TRANSACTIONS

OF THE

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Patron:—HER MAJESTY THE QUEEN.

President:—H.R.H. THE PRINCE OF WALES, K.G.

Volume V.

SECTION V.

CHEMISTRY AND PHYSICS IN RELATION TO HYGIENE.

EDITED BY C. E. SHELLY, M.A., M.D.

Assisted by the Honorary Secretaries of the Section.

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SECTION V.

CHEMISTRY AND PHYSICS IN RELATION TO HYGIENE.

Tuesday, 11th August, 1891.

The President, Sir Henry Roscoe, M.P., LL.D., F.R.S., in the Chair.

Presidential Address

BY

Sir Henry Roscoe, M.P., F.R.S., LL.D., D.C.L.

The branch of the great subject of Hygiene with which we in this section have to deal, viz., that of the relation in which it stands to the sciences of chemistry and physics, is one of primary importance and interest. Indeed, taken in its most general sense, the relation of the science of health to chemistry and physics will be found to include almost all the varied subjects which come under the cognisance of this Congress, for all vital processes are regulated by chemical and physical laws, and physiology may be defined as the chemistry and physics of the animal body. Hence the preservation of a normal condition, or of health, being dependant upon these laws, it is clear that our Section is the most important of all, for it is by obeying chemical and physical laws that health is maintained, whilst by neglecting to follow them we court disease and death.

But whilst as chemists and physicists we may claim credit for laying the foundations of the edifice of Hygienic Science, we gladly admit that portions of the building have been raised by other hands, and heartily do we welcome the successful efforts which the biologist, the physician, the engineer, and the statesman have made to help us to complete the building up of a condition of things by which the amount of preventible disease is reduced to its possible minimum, and that of health and well-being increased to the maximum possible under the necessary circumstances of our lives.

As to the progress which during the last half century has been made towards the attainment of this end—he who runs may read. Those who can carry their minds back 50 years will be free to confess that at that time, whether in England or abroad, the principles of Sanitary Science were recognised only by a very few men of light and leading, and that any attempt to carry out these principles were, indeed, few and

far between. Fifty years ago our notions of the nature of contagion, of the causes which lead to the spread of epidemic diseases were of the crudest and vaguest description. We then had no idea of the fact now not only proved beyond doubt, but strongly impressed on the public mind, that both water and milk are fertile carriers of disease if contaminated even ever so slightly with infectious material.

In those days "pump" water was believed to be wholesome if only it was cool and sparkling, and water from a source now recognised as dangerously impure was preferred to the pure article which came from a distance in the city mains. Now the sanitary authority closes all doubtful wells, and municipalities incur vast expense in bringing home to every one a pure supply of this necessity of life. Still much remains yet to be done for an adequate supply—especially in rural districts where the village pump is too often the sole means of existence, and where that pump is not infrequently in close proximity to sources of dangerous impurity. Moreover, even where the supply is of good quality, its quantity often fails in dry seasons from lack of any impounding system of the flood waters. That 50 years since our knowledge of these matters was limited is due to the fact that in those days chemists were unable to decide whether a water was harmless or dangerous. The methods of analysis were then crude and insufficient; and even now, when these methods have been greatly improved, the most expert analysts may find themselves in disagreement, on a mere chemical examination, as to whether a given water is fit to drink or not. The discussion of these methods of examination on Thursday next may, I should hope, contribute to the elucidation of these doubtful points.

Fifty years since no one realised that the existence of cesspools under their houses, of which there were then thousands in London, was a source of danger to the inhabitants. The idea of getting rid of and of utilising fœcal matter was laid hold of ages ago by nations, such as the Chinese, whom we in our wisdom term barbarians, whilst the civilised European waited till the middle of the nineteenth century before he discovered that if he would preserve his life he must remove from his neighbourhood the refuse which accompanies that life, and even now, at the end of the century, he is far from having solved the question of the best way of its removal, much less that of its utilization. On Wednesday next we shall have an opportunity of learning the opinion of those competent to give it on the much vexed questions of the chemical and physical principles involved in the treatment of sewage; and if we can lay down, even in outline, what these principles are, our section will not have met in vain.

The question of air pollution, which will come on for discussion during our sittings, is a much more difficult though an equally important one. We can bring pure water into our houses by pipes, we can also take away the polluted water by sewers, we can see the fresh water running in, and we know, if our drains are in order—an assumption it is true, and perhaps a bold one—that our dirty water at least goes away from us. In the case of the air, we cannot regulate the fresh supply so easily; nature, it is true, does much for us, indeed if she did not, we should be badly off. We cannot see the air, whether pure or otherwise;

our sense of smell, may, if it be sensitive—which is again an assumption often incorrect—possibly tell us that something is wrong, though it by no means follows that an odourless air is pure and healthy; but to ascertain how far the air is impure, and to express it in figures was, so far as concerns many of the most important of these impurities, impossible 50 years ago, and is only now beginning to be understood. But even were we able to detect the presence in the air of the spores of the as yet undetected influenza microbe we should be far from having a means of freeing the air from it. By filtration through cotton wool, air can be obtained practically free from microbic life as well as from dust particles and fog, but such air filtration can only be adopted in a very limited number of cases, and is altogether useless for general purposes. One of these few instances is that of the House of Commons, where a system of air filtration has been successfully adopted, by which the air of the debating chamber has been preserved perfectly free from fog as well as from microbic life if the doors are kept closed.

The discussion on town fogs and their prevention, which is to be introduced by Dr. Russell, will enable us at any rate to form an idea of the causes and possible mode of preventing these serious drawbacks to a city life. A scientific inquiry, if it does not at once succeed in finding a cure for the evil may, at least, point the way to prevention, and I shall be surprised if we do not find that the ultimate panacea will consist in using gaseous fuel and the electric light.

Another source of air pollution, more easy to grapple with, lies in the escape of deleterious gases from chemical works and other manufactories. The removal of many causes of such pollution has been satisfactorily accomplished in this country under what are known as the Alkali Acts, or more properly the Noxious Vapours Acts. Thanks to the care with which these Acts have been worked both by the Government inspectors and the manufacturers themselves, the serious complaints which arose of nuisance due to the escape of acid and other noxious vapours are now no longer heard; and not only has the public been the gainer by the stoppage of the escapes which formerly occurred, but the manufacturers themselves have also benefited, inasmuch as they have had their attention directed to improvements in their processes which have proved remunerative.

The great smoke question is one upon which I hope some light will be thrown by the discussion which will take place during our meeting. Much, doubtless, can be done in preventing the output of smoke from factories and other places in which large quantities of coal are burnt, but, after all, the smoky atmosphere of our towns is caused chiefly by the thousands of domestic fires, and at once to alter these so as to prevent smoke, or to insist upon gaseous fuel being generally used instead of coal, is to expect the impossible.

I have said that the foundation of hygienic progress is to be sought in the application of chemical and physical principles. This is true not only of the matters of every day experience to which I have already referred, but also of the most recent and astounding discoveries, showing the dependence of the health of the community on the actions of microbic life. Thus Pasteur and his pupils have proved that these actions on the

host or body receiving the microbes as guests, are to be attributed rather to definite chemical products formed by the living micro-organisms than to the organisms themselves. For just as in the well-known instance of the vinous fermentation, the products of the action of the yeast plant on sugar are alcohol, carbonic acid, and subsidiary compounds, so each definite micro-organism—such, for example, as that peculiar to diphtheritis—engenders certain active chemical principles which are capable of effecting serious or fatal changes, characteristic of this disease, within the animal body. Hence the ultimate causes of epidemic disease rest upon a chemical basis, and as we find in a simple chemical an antidote for poisoning by any of the commoner chemical poisons, so it would appear that an antidote for hydrophobia, for example, is to be found in the complicated chemical products of the life of the micro-coccus characteristic of this disease. How these antidotes—except in the most simple cases, such as acid and alkali and the like—act is as yet unknown. We do, however, know that the growth and life functions of this yeast plant are stopped in presence of an excess of the poison, alcohol, which it secretes, and this fact may help us to explain, to some extent, the protective action exerted by the chemical poison developed by many pathogenic micro-organisms. The elucidation of this subject, all-important for the health of the community as well as of the individual, is one of the most pressing scientific needs of the day. To isolate the various chemical products, to study their actions, both chemically and pathologically, is a necessary step towards the attainment of the end which we all have in view, viz., the prevention and cure of disease. Hence, it will be admitted by all, that whilst the determination of the morphological characters of micro-organic life is an essential preliminary, it is to the examination of the life-functions of the organism, and especially to those connected with the production of its peculiar chemical poison, that we must look for the complete solution of the problem; and therefore it is in the laboratory of the chemist, and by the application of chemical and physical methods of research that progress in these matters will, in the coming time, be made. So again, I say that the foundations of hygienic progress are to be sought in the application of the principles of chemistry and physics.

And now, gentlemen, I know that all well-wishers to this progress, whether English members or the foreign guests who have honoured the Congress by their presence, will rejoice to learn that we in England, determined no longer to lag behind our continental friends, are about to establish a National Institute of Preventive Medicine, in which not only researches of the kind I have alluded to can be satisfactorily carried out, but where instruction in the numerous special branches of science, upon which the health of the nation depends, can be given. Those who have interested themselves in this movement feel that it is no less than a national disgrace, that whilst almost every other civilised nation has established an institute of the kind in its midst, we in England should stand alone inactive and supine. We believe that the necessity for such a national institute only requires to be made generally known to be universally acknowledged, and we feel confident that now having

obtained the first step towards the attainment of our object, viz., recognition under license of the Board of Trade, the Council of the Institute will only have to ask in order to obtain the considerable amount of pecuniary support necessary for carrying on the work of the institute on a scale worthy of the country. This support must come wholly from private sources; for our Government, unlike that of many countries, as yet holds aloof from supporting institutes of this kind however necessary they may be to the general well-being of the country. The time may not be far distant when different views will prevail, and when Parliament will consider it one of its first and most binding duties to support by Imperial grant an institution whose sole aim is that of increasing our knowledge of the conditions upon which the health of the nation ultimately depends, and of diffusing that knowledge widely throughout the land.

A vote of thanks was accorded to Sir Henry Roscoe on the motion of Dr. Russell, seconded by Professor Odling.

On Town Fogs and their Effects.

BY

Dr. W. J. Russell, F.R.S.

Until 1880 the formation of fog was looked upon as arising simply from the separation of liquid water, probably in the form of hollow vesicles, from an atmosphere saturated with aqueous vapour; but in that year Aitken showed that the determining cause of the separating out of liquid water, and consequent formation of fog, was dust present in the air. He pointed out that a change of state, a gas passing to a liquid or a liquid to a solid, always occurred at what he terms a "free surface"; that as long as a molecule of liquid water is surrounded by like molecules (and the same with gaseous water) we do not know at what temperature, or whether at any temperature, they would change their state; but if in contact with a solid, then—at the surface where they meet—the change will occur. If the solid be ice it may become liquid; or the liquid may become solid; and the same kind of action occurs when the liquid is in contact with its own vapour. In fact, what we call the freezing and boiling points of a body are the temperatures at which these changes take place at such free surfaces. The dust always present in the atmosphere offers this free surface to the gaseous water, and thus induces its condensation. This specific action of dust varies very considerably,—first with regard to its composition, and second with regard to the size and abundance of the particles present. Sulphur burnt in the air is a most active fog producer; so is salt. Many hygroscopic bodies form nuclei having so great an affinity for water that they can cause its condensation from an unsaturated atmosphere. At the same time non-hygroscopic bodies,

such as magnesia and many others, are powerful fog-producers; no doubt their activity may in part be attributed to their being good radiators of heat, and thus by becoming cooled, inducing condensation. Mr. Aitken also showed that the products of combustion, even when the combustion is perfect, are powerful fog producers,—a fact which has an important bearing on the production of town fogs. One other point in these experiments I cannot omit mentioning; it is the exceedingly minute amount of matter capable of inducing fog. In his first series of experiments, Mr. Aitken showed that $\frac{1}{100}$ of a grain of iron wire, however often it was heated, evolved on each heating sufficient dust to cause a visible fog; and afterwards, with still more delicate apparatus, that $\frac{1}{2000}$ of a grain of either iron or copper when treated in the same way gave a similar result; and from these last experiments he infers that even $\frac{1}{100000}$ grain of either wire, if only slightly heated, would yield sufficient nuclei to cause a visible amount of fog. It is of much importance and interest, seeing how small a quantity of dust is required for the production of fog, to know that even this small amount may be filtered out of the air by passing it through cotton wool, and that an air may thus be obtained in which a fog cannot be produced. Mr. Aitken's description of such an atmosphere is at first most alluring; for he says that if there was no dust in the air there would be no fogs, no mists, and probably no rain; but he goes on to state that when the atmosphere became burdened with supersaturated vapour, it would convert everything on the surface of the earth into a condenser, every blade of grass and every branch of a tree would drip with moisture deposited by the passing air, our dresses would become wet and dripping, and umbrellas useless; but our miseries would not end here, for the inside of our houses would become wet, the walls and every object in the room would run down with moisture. I think if we picture to ourselves this state of things we may be thankful that there is dust—and fog. Dust in its finer forms is invisible to us, but as its delicate particles become loaded with moisture, it becomes a fine mist, which is dense if the number of particles are many. But if the dust particles are fewer, the amount of aqueous vapour remaining the same, each particle will have a larger amount of condensed moisture to carry, and will give rise to a more coarse-grained fog; the moisture, or some of it, will be more feebly attached to its nuclei, producing then what is known as a wet fog; whereas at least one most important fact in the production of a dry fog is the strong affinity between the nuclei and the condensed vapour. As most of you are no doubt aware, Mr. Aitken has invented a most ingenious method for counting the number of dust particles in air, and has obtained most interesting and valuable results. I can only mention here that some of these results deal with the clearness of air in relation to the number of dust particles present; and other results show how little effect rain has in diminishing the amount of the finer dust in air. Towns obviously supply dust of all kinds, and therefore offer every inducement for fogs to form, and some at least of these dust particles will be capable of causing the condensation of moisture even from an atmosphere which is not saturated with aqueous vapour. This condensation of moisture is a very complete process for removing all kinds of impurities from the air. Floating

particles are free surfaces, and, becoming weighted by the moisture they condense, tend to sink; even the gaseous impurities in the air will be dissolved and carried down by the moisture present. Experiment confirms this, for it has been proved how correctly the impurities of an air can be ascertained by determining the composition of dew, even if this be artificially and locally formed. It is of importance to note that even the purely gaseous emanations from our towns cannot pass away when a fog exists, as is shown by the accumulation of carbonic acid which takes place during a fog. Taking four volumes in 10,000 volumes as the normal amount of carbonic acid in London air, some years ago I found that it increased in the case of a dense fog to as much as 14·1 volumes, and often to double the normal amount, which must represent a very serious accumulation of the general impurities in the air.

A fog in this way becomes a useful indicator of the relative purity of the atmosphere in which it forms. If pure aqueous vapour be condensed it gives a white mist—a country fog, a sea fog—and a white light seen through it is not converted into a red light; but in town fogs the whiteness of pure mist disappears and becomes dark, in some cases almost black, in colour, the change being produced by the foreign matters floating in the air. By far the most abundant colouring matters of our town fogs are the products generated by the imperfect combustion of coal, but in addition to these bodies, many others must obviously find their way into the air over a town; especially will there be dust from the universal grinding and pounding going on in street-traffic and many mechanical operations, from the general disintegration of substances and the decomposition of perishable materials, all of which will add something to the air, and will become an integral part of the fog. However, although it is often said that a town fog is so dense that it may be cut with a knife, still it is difficult to condense so much of it that it can be subjected to a searching chemical analysis. In 1885 by washing foggy air I was able to determine the amount of sulphates and chlorides present, and—as indicators of organic matter—the quantity of carbon and nitrogen in the fog. The results showed strikingly how largely the amounts of organic matter and of ammonia salts in the air varied with the weather. No case of dense fog occurred when the experiments were being made, but the mean of several experiments clearly showed that in foggy weather the amount of organic matter was double as much as existed in the air in merely dull weather, and that the amount of sulphates and chlorides increased under like conditions, but not to the same extent. Fog may, however, be made to give its own account of its constituents; for we have only to collect and analyse the deposit which it leaves to learn what its more stable constituents are. We have to thank the air analysis committee of the Manchester Field Naturalists' Society for the most complete analysis of such a deposit which has yet been made. The deposit analysed occurred during the last fortnight in February of this year, 1891, and was obtained from the previously washed glass roof of the plant houses at Kew, and from Messrs. Veitch's orchid houses at Chelsea. At Kew 20 square yards of roof yielded 30 grammes of deposit. At Chelsea the same area gave 40 grammes,

which represents 22 lbs. to the acre or six tons to the square mile, and the composition of these deposits is as follows :—

———	Chelsea.	Kew.
Carbon - - - - - -	39·0	42·5
Hydro-carbons - - - -	12·3	4·8
Organic bases (pyridines, &c.) - - - -	2·0	
Sulphuric acid (SO_3) - - - - -	4·3	4·0
Hydrochloric acid (HCl) - - -	1·4	0·8
Ammonia - - - - - - -	1·4	1·1
Metallic iron and magnetic oxide of iron - -	2·6	41·5
Mineral matter (chiefly silica and ferric oxide) - -	31·2	
Water, not determined (say difference) - -	5·8	5·3
	100·0	100·0

These analyses give, I believe for the first time, a definite account of the composition of fog deposits. Soot and dust rendered sticky and coherent by hydrocarbons are by far the principal constituents, but I should like to give you the striking description which Professor Thiselton Dyer has sent me of the deposit collected at Kew. He says "it was like a brown paint, it would not wash off with water and " could only be scraped off with a knife. It thickly coated all the " leaves of the evergreens, and upon what have not yet been shed it " still remains." In the above analysis it is curious to note the large amount of metallic iron and magnetic oxide of iron. The details with regard to these very interesting analyses we shall hear from a member of the Manchester Committee, and I will only ask you to note how large a proportion of these deposits arises from the imperfect combustion of coal. We also learn from the Manchester Committee some interesting facts with regard to fog deposits which occurred last winter in their city. The deposit which was collected from aucuba leaves contained as much as 6 to 9 per cent. of sulphuric acid, and 5 to 7 per cent. of hydrochloric acid, mostly of course in a state of combination, but the deposit was, they say, "actually acid to the taste." Moreover, three days' fog deposited per square mile of surface, in by no means the worst part of Manchester, $1\frac{1}{2}$ cwts. of sulphuric acid, and even as far out of the city as Owens College, on the same area, over 1 cwt. of acid and 13 cwts. of blacks.

There is still one other point characteristic of town fogs to be noted; it is their persistency in an atmosphere considerably above the dew point. A country fog under such circumstances at once passes away; a town fog apparently does not do so. There seem to me to be two reasons for this; one is that the moisture is protected, and its evaporation to a large extent hindered, by the presence of oily matter; and secondly, that when the moisture has really gone, the soot and dust remain to produce a haze. The great distances to which fogs will travel is also remarkable, for they have on many occasions been traced to a distance of at least 25 to 35 miles from London, and I believe I might say to 50 miles.

I have so far discussed the production and composition of town fogs; and before considering their effects, would say a word

on the question of whether in London they are increasing in frequence and density. A complete and accurate record of fogs in London is not kept; several stations are required, and a correct method of registering the density and of distinguishing the difference between haze and fog is necessary, but fortunately there is a fair approximation to this complete registration of London fogs published by the Meteorological Office in their daily reports. The observations are made every morning at Brixton and every afternoon at Victoria Street; and, from a paper by Mr. Brodie on "Some remarkable features in the winter of 1890–91" published in the journal of the Royal Meteorological Society, I learn that the number of fogs thus registered as having occurred each winter since 1870 is as follows:—Winter being represented by the months, December, January, and February. I have divided these 20 years into four groups or five years each—

Between	1870–1875 - - -	93 fogs occurred.
,,	1875–1880 - - -	119 ,,
,,	1880–1885 - - -	131 ,,
,,	1885–1890 - - -	156 ,,

It appears, then, that during the last 20 years there has been a steady increase in the number of winter fogs. I am not aware of any data to prove whether the density of these fogs has increased, but it is probable that the increase in number of fogs largely depends upon an increase of atmospheric impurity, and on the conversion of haze and mist into obvious fog; and as the great colouring matter of fog arises from the combustion of coal, I have drawn up the following table from information which has been kindly furnished to me by Mr. G. Livesey and Mr. T. B. Scott, of the Coal Exchange. It gives the amount of coal really consumed annually in London, but does not include the coal used by the different gas companies.

COAL CONSUMED IN LONDON.

(That used by Gas Companies deducted).

Year.	Tons.
1875 - - -	4,882,233
1876 - -	4,988,280
1877 - - -	4,143,909
1878 - -	4,973,147
1879 - - -	5,833,891
1880 - -	5,334,823
1881 - -	5,598,281
1882 - -	5,343,974
1883 - - -	5,872,310
1884 - -	5,669,281
1885 - - -	6,026,063
1886 - -	6,096,732
1887 - - -	6,231,956
1888 - -	6,463,498
1889 - -	6,390,850

For the first five years the amount given in the table is rather too high, as the quantity used by the surburban gas companies could not be ascertained and deducted. The quantities apply to what is known as

the London district, an area with an average radius of 15 miles round London. The table shows an absolute increase during the last 15 years of two million tons of coal, that is, half as much again is now burnt as was burnt in 1875.

Supposing only 1 per cent. of sulphur in this last yearly amount is converted into sulphuric acid ($H_2 SO_4$) and passed into the air, it would give 195,720 tons of this acid. The five years' averages of winter fogs give a steady increase, but obviously the number in each winter will vary much with the atmospheric conditions; for instance, last winter was remarkably favourable for the development of fog; for again taking the figures of the last 20 years, the average number of days of fog during the winter is 25, but last winter the actual number was 50. A form of fog well termed "high fog" now frequently occurs in London. The lights in a street during this form of fog are often as visible as on a clear night, but above hangs a fog so dense that the darkness of night prevails during the day. This particular form of fog appears to have become much more frequent of late years; in fact it is doubtful whether in former times it ever occurred. The immediate cause of this new form of fog is difficult to explain.

The general atmospheric conditions which induce fog are a still and moist air and a high barometer—a state of the air most usual under anticyclonic conditions. The immediate determining cause, however, of a fog is usually a sudden and considerable fall of temperature. Mr. Brodie also points out that last winter was a time of calms; the percentage of such days on the average for the last 20 years is 9·7, but last winter the number was 22; emphatically, he says, it was an anticyclonic winter.

London has always been the head-quarters of town fogs, but now all the large towns appear to be imitating it in this respect. This is what we must expect, for an increase of population means an increase of combustion of coal, and that means a pouring into the atmosphere of more and more carbon, hydrocarbons and sulphuric acid; in dry and windy weather all these bodies may be scattered so as not to produce appreciable effects, but let the air be still, or even approach a state of aqueous saturation and then, as we have seen, every particle of dust and dirt becomes a centre for moisture to deposit on, and we shall have a fog imprisoning all impurities and offering them to us for inhalation. To burn coal so that only products of complete combustion may escape is a problem of much difficulty and is comparatively rarely done. Certainly the domestic fireplace does not do it, but, on the contrary, is the principal cause of the dark colour of our fogs. Many manufacturers, however, liberally contribute to produce the same effect.

I turn now from the constitution and production of fog, to note some of the effects it produces. First, with regard to health; details on this point I leave to those who are more able to describe them than I, but I have a few words to say with regard to the effect of London fogs on the death-rate in general. There are many people who feel so strongly the unpleasantness of fog that it induces them to magnify its results and make extraordinary statements with regard to the mortality it produces. It has even by some been likened in deadliness to the Great Plague of London and to other great epidemics. To ascertain how far such views

were correct I studied the Registrar-General's reports for the times of fogs, and expressed his results by the curves drawn on a series of diagrams.* I selected times of fog, viz., the winters of 1879–80, 1889–90, and 1890–91, and represented graphically the temperature, the amount of fog, and the death-rate for each day. The results are, I think, worthy of careful study. The first thing learned from these diagrams is that by far the greater number of fogs occur when there is a great fall of temperature; this is closely followed after a few days by a great increase in the death-rate; how much of this increase is to be attributed to the fog and how much to the fall in temperature may be difficult to determine. We have evidence that when fogs occur without fall of temperature, they do not appear to be followed by any remarkable increase of death-rate, for on December 15th 1889 there was a dense fog and the temperature was even above the average, and under these conditions the death-rate remained far below the average; on December 13th and 14th in the same year again there is a dense fog, and average temperature, and only an average death-rate, and the same thing happened on February 4th in 1890, when, notwithstanding a dense fog, the death-rate remained remarkably low; and last winter on November 13th and 14th there was again a dense fog, a high temperature, and an average death-rate. With these four exceptions, depression of temperature goes with fog. There is no case of depression of temperature not followed by increase of death-rate.

That many people suffer much, both physically and mentally from the effects of fog there can be no doubt; but as far as I can interpret these returns of the Registrar-General, they do not confirm the popular impression that fog is a deadly scourge; at the same time it is beyond doubt that an atmosphere charged with soot, dust, and empyreumatic products is an unwholesome atmosphere to breathe; though I think that the principal cause of the great increase of mortality when fogs occur is attributable rather to the sudden fall of temperature which usually accompanies fog than to the fog itself.

So many toxic effects are now traced to the action direct or indirect of bacteria, that it is satisfactory to learn from the experiments of Dr. Percy Frankland that fogs do not tend to concentrate and nurture them; for he found there were remarkably few bacteria in London air during a time of fog.

The deleterious action of town fogs on plants is more marked and more easy to investigate than its effects on animals. Nurserymen have long known from experience that a town fog will penetrate even their heated greenhouses, and will with certainty kill many of their plants, especially their orchids, tomatos, and in fact most tender and soft-wooded plants. But on this point I cannot do better than quote what the Director of Kew Gardens, Professor Thiselton Dyer, says in a letter to me:—" With regard to plants under glass the " effect of fog is of two kinds. i. By diminishing light. This checks

* The diagrams here referred to were exhibited at the Congress.

" transpiration. The plants are therefore in the condition of being
" overwatered, and a well-known consequence of this is to make them
" shed their leaves wholesale. Many valuable plants which ought to be
" well furnished with foliage become perfectly bare and it is impossible
" ever again to recover them into sightly specimens. ii. The toxic
" influence of the fog. This is most striking. It is illustrated in the
" most forcible way by the enclosed memorandum.* I attribute it in the
" main to sulphurous acid though I cannot help suspecting that some
" hydro-carbon may also have something to do with it. The toxic
" effect varies from one plant to another, some are scarcely injured
" others are practically killed." He adds, "I hope you will be able to
" arouse some interest in this horrible plague. If the visitation of last
" year is annually repeated it must in time make all refined horticulture
" impossible in the vicinity of London." I append to this paper the very interesting and important report from Mr. W. Watson to which Professor Dyer refers. This fog action on plants is so clearly marked and so deadly that it has, I am happy to say, led the Horticultural Society, aided by a grant from the Royal Society, to undertake a scientific investigation of the matter. Plants are so much more easily dealt with than people—all the circumstances of their attack by the fog and its immediate results are so much more easily noted and traced—that the investigation has already yielded important results, and we shall, I hope, hear from Professor Oliver, who is devoting himself specially to the investigation, some account of his latest results. A marked and admitted difference between town and country fogs is, that while a country fog is harmless in a greenhouse, a town fog will produce most destructive results.

There is still another action of town fogs and one which I believe is of the greatest importance. I mean its power of absorbing light. This power of abstracting light depends principally on the amount of coal products which the fog contains. The slower vibrating red rays can struggle through a fog which is absolutely impervious to the more refrangible ones. Even a mist but slightly tinged with smoke is opaque to the blue rays and this screens us from their action; but, as Aitken has lately shown, the heat rays can pass through readily. This opacity of town fog to light is, I believe, one of its most serious and detrimental characters; animals can no more thrive in semi-darkness than can plants, and important as the red rays may be, still it is undoubtedly the blue rays which are most active in producing the principal chemical changes going on around us. Experiments lately made have strongly impressed me with the wonderful activity which light confers on a mixture of air and moisture. Oxidations which in dulness and darkness are impossible, are easily and rapidly effected by aid of a gleam of sunshine, or even by a bright diffused light. It is not possible, I believe, for people to remain healthy where this source of chemical activity is cut off or even seriously diminished. In addition to the loss of physical energy, mental depression is induced by the absence of light; the whole tone of the system becomes

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* *Vide* Appendix to this paper.

lowered and may fall a prey to actions which under brighter conditions it would have been able to resist.

There is another action of light which is potent for good. I mean its destructive action on many forms of bacteria. Professor Koch at the last meeting of this Congress pointed out how his tubercle bacilli are killed by even a short exposure to sunlight, and it is now well established how inimical light is to the growth and development of most kinds of bacteria. I wish I could show you in some perspicuous way the enormous power which town fog has of absorbing light, and bring forcibly before you the great difference which exists between the amount of light which reaches the inhabitants and buildings of a town as compared with the amount on an equal area free from smoke. A simple actinometer is much required, and I hope the want will soon be supplied; but at present the only records bearing on this point are the observations of direct sunshine made at various stations by the Meteorological Society and the Meteorological Office with the Campbell-Stokes instrument, and some interesting observations by Mr. H. Raffles on the distance at which objects were visible during a London winter. First with regard to the sunshine experiments. One station is situated in the heart of the city, in Bunhill Row, and it is of much interest to compare the amount of sunshine there with, first the amount in the immediate neighbourhood of London, where we are not beyond the effect of town fogs, viz., at Greenwich on one side and at Kew on the other, and also with a place not far from London which is beyond the influence of its smoke, viz., Aspley Guise, near Woburn. I have also noted the results obtained at Eastbourne, which is about as far distant from London as Aspley Guise, but in the opposite direction, and is one of the sunniest places in England.

Hours of Sunshine during the year 1890.

Month.	Bunhill Row.	Greenwich.	Kew.	Aspley Guise.	Eastbourne.
January	29·9	44·0	56·0	57·3	56·9
February	42·4	62·8	57·8	70·5	106·5
March	71·3	90·8	109·3	110·4	133·5
April	127·4	141·5	144·8	137·3	170·1
May	215·7	223·9	223·9	214·3	267·9
June	128·0	125·2	141·4	119·1	165·3
July	134·1	120·6	139·9	141·3	185·6
August	164·0	153·1	182·5	189·5	200·2
September	131·6	153·2	169·5	166·1	207·4
October	89·6	96·9	121·6	135·6	125·3
November	23·4	40·8	57·6	64·7	66·9
December	0·1	2·4	0·3	13·4	38·0
Total	1157·5	1255·2	1404·6	1419·5	1723·6

Taking the totals of last year, the table shows that the hours of sunshine registered at Bunhill Row was 1158, at Greenwich 1255, at Kew 1405, at Aspley Guise 1420, and at Eastbourne 1724. But for our present purpose we must compare the amounts of sunshine at these

places during the winter months, November, December, January, and February, and we find that at Bunhill Row there were 95·5, Greenwich 150, Kew 171·7, Aspley Guise, 205·9 and at Eastbourne 268·3 hours of sunshine; that is, if Aspley Guise be taken as giving the normal proportion, Bunhill Row received only half its due amount, and at Eastbourne there was nearly three times as much sunshine as in the city. Now, on comparing the two other periods of four months which are comparatively free from fogs, the amount of sunshine is far more nearly equal at all stations.

——	Bunhill Row.	Greenwich.	Kew.	Aspley Guise.	Eastbourne.
March till June -	542·4	581·4	619·4	581·1	736·8
July till October -	519·3	523·8	613·5	632·5	718·5

Mr. Raffles, during the winter of 1887–88, which it should be noted was remarkably free from fogs, made a series of observations of the distances to which he could see from Primrose Hill, and found that looking south on the 152 consecutive days from November to March, only on 78 days could he see a quarter of a mile, and only on 83 days could he see to the same distance in a south-westerly direction. This conveys a good idea of the opacity of our London atmosphere.

We attempt to compensate for the darkness which fogs cause by the use of artificial light, and I have again to thank my friend Mr. Livesey for the information he has given me with regard to the extra quantity of gas burnt in London during a day of fog. He tells me that if a dense fog covered the whole of London and lasted all day, the additional amount of gas consumed would be 30 million cubic feet; but since so extensive a fog as this probably never exists and certainly never lasts all day, the actual amount consumed may be correctly reckoned at 25 million cubic feet; and, if the cost of this be calculated at 2*s*. 6*d*. per 1,000 cubic feet, which is rather below than above the actual cost, it amounts to 3,125*l*. But after all it is not the single days of dense fog that measure the extra amount and cost of artificial light used on account of fog; it is rather the continually occurring dull days and local transitory fogs which demand an extra supply of gas; and this is often 5 to 15 million cubic feet in a day, and gives a total by the end of the winter which is very considerable. As a standard of comparison I should state that the total consumption of gas in the London district in a day of 24 hours during the depth of winter is 140 million cubic feet.

Such then is an imperfect outline of the chief features and effects of town fogs; and now, what is to be said with regard to the possibility of getting rid of such fogs? This question, it seems to me, resolves itself into this; fogs cannot be prevented from forming over towns; there are, and probably ever will be, special inducements in the way of dust particles and products of combustion for fogs to form; but whether they must always be dark in colour and loaded with soot and

tarry matter is another question. The answer involves not only chemical but also social considerations. With regard to the first, my answer is, that as long as coal is burnt you will have dense fogs; grates, kitcheners, furnaces may be, and probably will be, much improved and fires may be stoked in a better way, but that the improvements will be so great that all imperfect combustion will cease I think is improbable. If this be so, there is only one other alternative, as long as coal is our source of heat, and it is to alter our form of fuel, to adopt gas and coke; the soot and tarry matters will be then done away with. The question of sulphuric acid in the air would remain, but our fogs would at least be white. There is still the social part of the question, which is not without serious difficulty, namely,—How to induce or to compel people to give up the use of coal? At the present day it would not be possible to do as it is recorded was done in the reign of Edward I.—try, condemn, and execute a man for burning coal in the city of London.

Appendix.

The Effects of Fog on Plants grown in the Houses at Kew. By W. Watson.

The heavy fogs experienced in the last two or three winters injured many plants in the houses at Kew. When thick fog occurred almost daily, the injury it did to many plants amounted practically to destruction. The leaves fell off, the growing point withered, and in some cases such as Begonias and Acanthads, the stems also were affected. Flowers as a rule fell off as they opened or whilst in bud. Almost all flowers which expanded were less in size than when there was no fog. The flower-buds of *Phalænopsis*, *Angræcum*, some Begonias, Camellias, &c., changed colour and fell off as if they had been dipped in hot water.

In the Palm House bushels of healthy-looking leaves which had fallen from the plants were gathered almost every morning. Plants which appeared to be perfectly healthy, when shaken would drop almost every leaf. Herbaceous plants suffered most; *e.g.*, Begonias, Poinsettias, Bourvardias, Acanthads, &c. Some herbaceous plants, however, did not suffer at all, nor were their flowers injured, as, for instance Cyclamen, Primula, Hyacinth, &c. Many hard-wooded plants lost their leaves and were otherwise damaged, viz., Boronias, some Heaths, Grevilleas, Acacias, &c. *Protea cynaroides*, a Cape plant with large laurel-like leaves, was much injured in the Temperate House (min. temp. 40°), the leaves turning black as though scalded. The same species, however, in another house where the atmosphere is drier and the temperature a few degrees higher, was scarcely affected by fog.

As a rule, the plants that were in active growth suffered most. Monocotyledonous plants and ferns for the most part were not appreciably affected by the fogs; the injury they suffered, especially last winter, being clearly due to low temperature. The effect of fog on flowers at Kew is remarkable. Generally white flowers are destroyed,

but there are some notable exceptions, viz., *Masdavallia tovarensis*, *Odontoglossum crispum*, and some *Angræcums* amongst orchids, and linums, white cyclamen, white hyacinths, white chrysanthemums, &c.

The green leaves of *Poinsettia pulcherrima* all fell off, whilst the red ones (bracts) remained, as also did the flowers. All Calanthes of whatever colour lost their flowers. The buds of the white-flowered *Angræcum sesquepedale* turned black as if boiled, whilst those of *A. eburneum*, also white flowered, were not injured and developed properly. These two plants are grown in the same house, under identical conditions, and they come into bloom about the same time.

The conditions most conducive to rest from growth, viz., a low temperature and a moderately dry atmosphere, together with diminished light—unavoidable in foggy weather—were proved at Kew to be the safest for all plants during the prevalence of heavy fogs.

The Air of Large Towns: Methods of Analysis.

PRESENTED BY

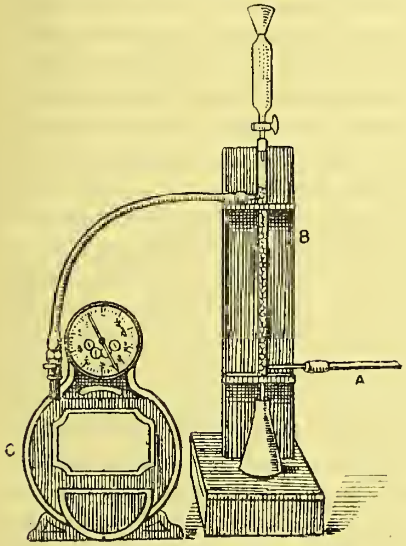
Mr. Hartog on behalf of the Air-analysis Committee of the Manchester Field Naturalists' Society, (Dr. Bailey, Dr. J. B. Cohen, Mr. Philip Hartog, and Dr. Tatham.)

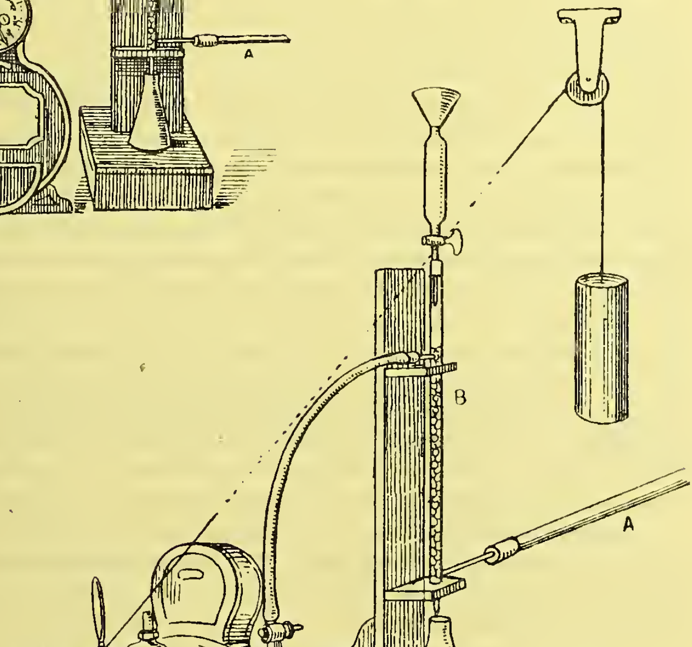
A general and systematic investigation is being made of the composition of the air of Manchester in the different parts of the city. Special attention is being paid to the following points: (*a*) The differences of composition in the air of thinly and of densely populated areas; (*b*) the relation between atmospheric impurity and prevalent sickness and mortality; (*c*) the extent to which smoke and noxious vapours are due to factories and to dwelling-houses respectively; (*d*) the character of the air during the prevalence of fog; (*e*) the relative amount of light in different districts.

The following paper contains a brief account of the preliminary results which have been obtained.

It was decided first of all to deal with the presence of sulphurous acid in the air, for the following reasons:—1. Sulphurous acid, and the sulphuric acid to which it gives rise by oxidation, are distinctly harmful, even in small quantities, both to animals and the higher plants. It seems probable that the effects of town fog are largely due to the excess of sulphurous acid which it contains. 2. We know definitely that the sulphurous acid of the air arises wholly and solely from the combustion of coal, which contains from 1 to 2 per cent. of sulphur. It is a pollution especially characteristic of our great cities, and is, in our opinion, a pollution which properly directed efforts may abolish. 3. The subject is one which has scarcely been touched by previous observers, owing to the difficulties of estimating sulphurous acid when it is largely

diluted with other gases, as in the atmosphere. We describe here a simple and accurate method which we have devised for its estimation.





The apparatus used consists of three parts—A, a long glass tube about half an inch in diameter, open at both ends, which is fixed horizontally so as to project into the open air; B, a glass tower about 30 ins. high and $1\frac{1}{4}$ ins. in diameter, open at the top, and drawn out

into a fine jet at the bottom. Two side tubes are fixed to the tower, one near the bottom and the other on the opposite side near the top. The tower is filled to within one inch of the upper side tube with glass beads, and into the open top a tap-funnel is inserted through a tightly fitting cork. The lower side tube is attached to the horizontal tube; the upper one by means of wide india-rubber tubing, to a combined meter and aspirator C. This is an ordinary wet-meter converted into an aspirator by attaching toothed wheels to the revolving drum and driving the wheels by means of a wire cord passing over a pulley and carrying a weight. A series of dials registers the volume in hundredths of a cubic foot. The method of conducting the experiment is as follows:—About 250 c.c. of a solution of hydrogen peroxide in water, containing about one milligram of active oxygen in each cubic centimetre, is poured into the tap-funnel, from which it is allowed to drop onto the glass beads at the rate of about one drop a second. The liquid passes down and out at the lower end of the tube through the jet, and falls into a flask placed below. A drop of liquid which permanently fills the jet seals it effectually from the entrance of air from the interior of the room. After running through, the liquid is poured back into the funnel. The weight being wound up, the volume indicated on the dial is read off, and the drum set in motion. With a column of beads of about 20 ins. and a weight of about 10 lbs., twenty cubic feet can be aspirated in an hour. Once started, the apparatus needs no further supervision until either the weight has reached the ground or the solution of hydrogen peroxide has run out of the funnel. The period required for this is readily determined, so that no time is lost in looking after the apparatus. A preliminary experiment made with an artificial atmosphere containing a known volume of sulphur dioxide, and a check tube with hydrogen peroxide inserted between the tower and the aspirator gave good results, and sufficiently proved the trustworthiness of the apparatus.

Determinations have been made simultaneously at the Owens College and at the Manchester Town Hall. The volume of air analysed has varied from one to three cubic metres. The results are given in milligrams per cubic metre:—

1891.	———	Owens College.	Town Hall.
February 18	White fog, no smell of sulphurous acid (morning)	3·14	—
February 18	White fog, slight smell of sulphurous acid (afternoon) - - - -	3·72	—
February 19	Slightly foggy at commencement only; clear rest of time (midday) - - -	1·95	—
February 19	Clear and sunny (afternoon) - -	2·10	—
February 19	Moonlight and clear (evening) - -	1·80	1·87
February 20	Clear (midday) - - - -	—	1·38
February 21	Clear (midday) - - - -	2·07	—
February 24	White fog and clear at close (midday) -	3·08	4·06
February 25	Clear and sunny (10 to 5)- - -	0·77	—
February 27	Foggy (9.30 to 12) - - - -	—	7·40
March 6	Very clear, wind (9.30 to 2.30) - -	0·28	—
March 12	Misty, bright sun (11.45 to 1.25) - -	0·97	—

The results show considerable variation in the amount of sulphur dioxide present in the atmosphere. The lowest result was obtained on March 6th, after two days' strong wind. The highest results were obtained on February 18th, 24th, and 27th, and on all these days there was a considerable amount of fog. The determinations made simultaneously at the Owens College and at the Town Hall show an excess of sulphur dioxide in the centre of the town.

Analyses of snow on successive days showed that during a three days' fog rather more than 1½ cwt. of sulphuric acid per square mile was deposited in the centre of the town; at an outlying station 1 cwt. of sulphuric acid and 13 cwt. of blacks per square mile was carried down during the same time.

The solid deposits on leaves of shrubs have also been analysed, and the results amply explain the difficulty experienced in growing plants and trees in towns. A series of observations on the clearness of the air, and on daylight intensity is also being made.

The organic matter in the air is to be estimated by a modification of the method used by Tidy in water-analysis. The committee adopts Dr. Russell's plan of collecting the dust, &c. by sucking a known quantity of air through glass wool, but instead of subjecting this wool to a combustion in oxygen, it is treated by dilute permanganate of potash, which is titrated back first immediately and then again after the lapse of a few hours.

An analysis was made of a deposit which was formed on plant-houses in London and supplied to the committee by the kindness of W. T. Thiselton Dyer, Esq., F.R.S., Director of Kew Gardens, and of Professor F. W. Oliver, of University College. It was found to contain:—

Carbon	39·00	per cent.
Hydrocarbons	12·30	„
Organic bases	2·00	„
Sulphuric acid	4·33	„
Hydrochloric acid	1·43	„
Ammonia	1·37	„
Metallic iron and magnetic oxide	2·63	„
Other mineral matter, chiefly silica and ferric oxide	31·24	„
Water (not determined)	—	

The committee is working in concert with a committee of the Royal Horticultural Society in London; and during the coming winter, with the aid of a grant from the Royal Society, experiments in Manchester and in the Metropolis will be carried on simultaneously.

DISCUSSION.

Dr. C. Theodore Williams pointed out the difficulty of determining how far the injurious effects observed in times of fog were due to the fog itself, or to the cold usually accompanying it. London fog was often fatal to people in a precarious state of health or suffering from advanced disease. With the majority it was not so, although it gave rise to various complaints that were not necessarily fatal. Fog induced thirst, smarting of the eyes, headache, coryza, bronchial catarrh, pharyngitis, bronchitis, and occassionally pneumonia. A prolonged period of fog also caused pallor and anæmia in a certain number of persons. He had noted that during the quarter ending March 31st, 1891, which had been a very foggy one, the Registrar-General's returns showed the mortality under one year of life to be 2·1 per cent. above the average of 20 years, and that of people over 60 to be 9·5 per cent. above the average; but the mortality of the population between one and 60 years of age to be 2·6 per cent. below the average, and this in spite of great cold and fog. He had observed cases of asthma in which the patient was benefited by a London fog, and even by the atmosphere of the Underground Railway.

Mr. Ernest Hart said that he was sure that Dr. Williams did not mean to imply that his experience of a few subjects of a disease so capricious as asthma had any general value. To create or tolerate London fogs for the sake of a few asthmatics, would be to burn down the house for the sake of roasting the pig. The mortality of London during the previous great fogs had been as great as in a cholera season. He enumerated a number of examples of the methods by which smoke might be diminished in private houses; the latter were the main sources of smoke in towns, and they affected not only the purity of air, but the amount of light, so that all London, Manchester, Sheffield, Wolverhampton, and other large towns were now, during a large part of the year, gigantic cellar dwellings. Mr. Hart mentioned the legislation suggested by the Smoke Abatement Society and approved by many local authorities, as well as by a Committee of the House of Lords.

Dr. Tripe (Hackney) agreed with Mr. Hart. In Hackney, as soon as the fogs set in, mortality increased, the effect of the fogs being to kill off those who were susceptible. Many asthmatics received quite as much benefit from breathing hydrocarbons as from a London fog.

Dr. Edward Haughton thought that there was urgent need of legislation in relation to smoke abatement, and considered that a small house tax should be imposed upon those who neglected to use grates of a proper construction. He regarded as sufficient the change recommended 90 years ago by Count Rumford, viz., the substitution as far as possible of closed grates for open ones, as the latter waste six-sevenths of the heat that is generated, besides loading the atmosphere with sulphurous acid and unconsumed carbon. The public must take the matter into their own hands and demand that their representatives should work for this reform.

Professor F. W. Oliver (Kew Gardens) drew attention to the nature and extent of the injuries caused by fog to vegetation, and gave an account of some experiments on this subject carried out under the

auspices of the Scientific Committee of the Royal Horticultural Society. He alluded in some detail to the action of sulphurous acid on vegetable protoplasm. In conclusion he referred to the work of the Manchester committee, and expressed the conviction that similar systematic records should be kept of the varying constitution of the London atmosphere.

Mr. Pridgen Teale, speaking of domestic smoke as the result of imperfect combustion, said that this could be in a great measure reduced by adopting in our fireplaces principles of construction now well understood, but violated in a large proportion of the grates produced by makers. Coal must be burned in as hot a grate as possible, viz., fire-brick, and the air should be admitted on the surface of the coal not through it, coal being burned in so large a mass as is consistent with the size of the room to be warmed.

Professor K. B. Lehmann (Würzburg), sagte:—Wir haben weniger Russ in unserer Stadtluft, aber unter schwefliger Säure leiden auch wir in Deutschland. Ich erlaube mir an die interessanten Untersuchungen zu erinnern, welche Sendtner auf Veranlassung von Pettenkofer unternommen hat. Dieselben ergaben ausser der Bestätigung einer Reihe der heute gehörten hochinteressanten Thatsachen, dass namentlich auch Statuen aus Marmor und Bronce stark unter schwefliger Säure leiden und dass letztere keine Patina ansetzen, sondern nur schwarz und rauh werden. Diese Thatsache ist für Kunststädte nicht ohne Bedeutung, wenn natürlich von weit geringerer als die hygicnische. Letztere wurde von Ogata und L. Pfeiffer im Laboratorium von Pettenkofer sorgfältig durch Thierversuche studiert.

Mr. B. H. Thwaite (Liverpool) said that several years' experience had satisfied him that the cause of the black and noxious fogs of large towns was the presence in the atmosphere of the volatile hydrocarbons and the sulphurous acid resulting from the imperfect combustion of bituminous fuel. The presence of these constituents, by interference with the solar heat and light, produced the lowering of temperature and the reduction of chemical effect of the solar rays in regard to organic life. He suggested for the metropolis the conveying of gas under high pressure from the coal districts in steel tubes; the London County Council to supply such gas to the inhabitants at a reasonable price, and thus to initiate successful municipal procedure in the provinces.

Mr. Hargreaves Raffles advocated the collection and comparison of statistics relating to town fogs from all large cities.

The following *Resolution* was moved by the President, and seconded by Mr. Ernest Hart:—

> "That the Section of Chemistry and Physics in relation to Hygiene requests the President of the Local Government Board and the Home Secretary to take into consideration whether legislative measures cannot be adopted to lessen the amount of smoke produced from dwelling houses, and thus to diminish the intensity and mitigate the evil effects of town fogs."

This resolution was carried unanimously.

The Means at our disposal for Preventing the Emission of Smoke from Factories and from Dwelling Houses.

BY

Alfred E. Fletcher, F.I.C., &c., H.M.'s Chief Inspector under the Alkali, &c. Works Regulation Act.

The complaints that have been raised against the black smoke arising from the combustion of coal are not of yesterday. Nearly six centuries ago there was a cry in London that such a nuisance was not to be endured, and a royal edict was issued by King Edward II. in the year 1316 that coal-burning should cease, and that if any self-willed citizen should continue the obnoxious practice, and still contaminate the air with that foul vapour, his house should be pulled down about his ears.

This peremptory order for a time sufficed to stop the objectionable practice of burning smoky coal, but how long its effect lasted it is difficult to determine. It would appear that the increasing scarcity of wood, and the excellency of coal as a fuel, forced the latter again into use in spite of king and commons, for, in later times, we find Parliament petitioning the King to issue an edict to stop the burning of coal, which had again come into use. Smoke, however, seems to have held its own in spite of all attempts at repression, although fresh efforts were continually made in that direction.

In the year 1829 a select committee of the House of Commons was appointed to inquire into the effect of the smoke from factory chimneys on the public health; and, in 1843, another committee was appointed to consider the "means and expediency of preventing the nuisance of smoke." No definite result is recorded.

Ten years later a determined step was taken by Lord Palmerston, then Prime Minister. He introduced a Bill making it penal to allow black smoke to issue from any factory chimney within the metropolis or from any steam vessel plying on the Thames above London Bridge. The fines imposed were heavy and cumulative. The Act is that of 1853 (16 & 17 Vict. c. 128).

In 1856 this was followed by an amending Act extending the prohibition of smoke to all steam vessels plying below London Bridge as far as the Nore, and including bakehouses and certain factories which had been kept out of the former Act.

A marked benefit was at once felt from the operation of these Acts. Steamboats on the Thames had been accustomed to vomit out huge volumes of smoke wholly out of proportion to their size, and factory chimneys in the eastern districts of London had filled the air with blackness. Now all was changed; these chimneys seemed to keep perpetual holiday, though, indeed, the fires beneath them were never brighter, while Old Father Thames passed on his way under clearer air,

and the gardens at the Temple and elsewhere on his banks rejoiced in flowers and shrubs hitherto impossible in the smoke-laden atmosphere.

The air of London was relieved of nearly all the smoke of factory chimneys by the operation of these Acts; but the smoke from dwelling-houses remained. In the foggy weather of winter the great evils arising from this latter source are so painfully brought to the knowledge of every Londoner that he is unconscious of the relief he has gained by the operation of Lord Palmerston's Factory Smoke Acts.

The administration of the Acts is placed in the hands of the Metropolitan Police, under the control of the Home Office. In this, London is distinguished from other parts of the country. Generally, the administration of the smoke clauses of the Health Act of 1875 are in the hands of the magistrates or other local sanitary authority; and, as these are often the principal offenders, it is not surprising that excuses are found for allowing the law to remain in abeyance.

The black smoke which rises from a coal fire consists of the volatile matter which is given off under the influence of heat and yet has escaped combustion. When combustion is complete no visible smoke is discharged; the escaping gas consists then only of carbonic acid and vapour of water or steam, together with some sulphurous acid resulting from the burning of the sulphur pyrites in the coal.

Visible smoke is the result of an imperfect combustion. The gaseous matter set free when coal is heated consists of various compounds of hydrogen and carbon; when these are burned with a quantity of air insufficient to inflame the whole, the hydrogen only is burnt, while the carbon remains in the form of the black matter or soot with which we are too familiar. This black residue is made apparent also when the combustion is rendered incomplete by deficiency of heat, even if there is a sufficiency of air or oxygen—as may be shown by introducing a piece of stout copper wire into the flame of a clear-burning wax candle. The cold wire diminishes the temperature of the flame, and, rendering the combustion incomplete, causes the formation of soot, part of which is deposited on the cold wire and part rises in smoke from the top of the flame. Or, again, combustion may be rendered incomplete if sufficient time be not allowed for the due mixing of the combustible gas with the air. There must be intimate mixture, so as to promote contact between the air and every particle of the gas to be burned.

There are, then, three conditions to be observed in order to effect the complete combustion of the gaseous mixture given off from strongly heated coal:—First, there must be sufficient air; second, the air must be mixed with the gas; third, this mixture must be raised to the temperature of ignition.

It may be necessary to dwell briefly on this last head, and to observe that the temperature of ignition varies with different substances. The temperature at which sulphur will ignite is much below that at which carbon will burn. Pure hydrogen also will ignite at a lower temperature than is necessary for hydrocarbons. These and the other gases which form the mixture given off on heating a bituminous coal require a heat approaching that of whiteness to ignite them.

Now if these three conditions for the combustion of coal gas be all observed the burning will be effected, but if the observance of any one of them be omitted complete ignition will not take place.

It may be said that in most furnace fires the first condition is fulfilled, except at the time when fresh fuel is put on. When a bituminous coal is thrown onto a hot fire a large volume of gas is suddenly generated; this fills for a time the draught passages, so that just when an increased supply of air is needed less air than usual finds access to the fire.

A very common cause of failure arises from a non-observance of the second condition necessary to complete combustion. The air, though admitted both above and below the fire, never mixes with the gases thrown off from it, but passes with them in parallel streams till they reach a place where the temperature is so low that ignition is no longer possible.

In the furnaces of steam boilers a very common cause of failure in combustion is the non-observance of the third condition. The gases rising from the fire, and mixed perhaps with the air needed for burning them, are in many cases hurried from the immediate neighbourhood of the fire, where alone a sufficiently high temperature is found, to the boiler flues, where, deprived of their heat, all combustion is impossible. This is especially the case in a so-called haystack boiler, often used on river steamboats, and very commonly on the Clyde. There the fuel gases rising from the fire are at once led through cold tubes surrounded by water. In such a case combustion, if commenced, is stopped and rendered impossible from want of heat, and the unburnt gases laden with soot pass on to the chimney.

Of the fuel used in manufacturing operations about two-thirds is employed for raising steam. It is necessary, therefore, in considering the problem of smoke prevention to direct special attention to the construction of the furnaces of steam boilers. The three conditions already shown to be necessary to complete combustion must be observed, and, beyond these, it is necessary to avoid as far as possible the admission of an excess of air if the maximum duty of the fuel is to be realised.

When a furnace is fed by hand the operations of stoking must necessarily be intermittent, and consequently the due proportion between the fuel and the air cannot be constantly maintained. The necessity also of opening the fire-door is a constant source of loss, in that an excess of cold air is drawn in which tends to cool the boiler. There is evidently then a danger, on the one hand, of supplying too little air and so causing the formation of black smoke, or on the other hand of supplying too much and so causing a loss of heat.

In order to ascertain the general composition of fuel gases passing as smoke up factory chimneys I made a series of experiments in 1888, analysing the gases from furnaces in Newcastle and in Lancashire, where different kinds of coal were used. The annexed table shows the results of the analyses. It will be seen that in all cases but one there was a very large excess of air, even when black smoke was emitted. The

Analyses of Chimney Gases.

Number.	Name of Firm.	Description of Furnace.	Remarks.	Smoky.						Slight Smoke.						Clear.					
				N	O	CO_2	CO	CH_4	H	N	O	CO_2	CO	CH_4	H	N	O	CO_2	CO	CH_4	H
			Hand Fired Furnaces.																		
1	Brunner, Mond & Co.	Lancashire boiler	Before and after stoking	80·65	8·6	10·25	0·5	0	0	—	—	—	—	—	—	80·0	9·75	10·25	0	0	0
2	Copley & Co., Middlesbro'	Marine boiler	S. Durham coal. Eldon nuts.	82·78	1·72	15·0	0·5	0	0	—	—	—	—	—	—	79·92	15·68	4·4	0	0	0
3	Dorman, Long, & Co. do.	Lancashire boiler	Large Trindon coal	79·75	18·75	1·5	0	0	0	—	—	—	—	—	—	80·25	18·50	1·25	0	0	0
4	" "	" "	" "	—	—	—	—	—	—	—	—	—	—	—	—	80·0	19·70	0·3	0	0	0
5	" "	" "	" "	—	—	—	—	—	—	—	—	—	—	—	—	83·55	8·65	7·8	0	0	0
6	Eureka Salt Co., Northwich.	Lancashire boiler	Steam jet used when stoking.	—	—	—	—	—	—	—	—	—	—	—	—	79·85	14·65	5·5	0	0	0
7	Eureka Salt Co., Northwich.	" "	Steam jet used when stoking.	—	—	—	—	—	—	—	—	—	—	—	—	80·55	9·45	10·0	0	0	0
8	Eureka Salt Co., Northwich.	" "	After stoking without steam jet.	—	—	—	—	—	—	80·75	10·45	8·8	0	0	0	—	—	—	—	—	—
9	Eureka Salt Co., Northwich.	" "	After stoking without steam jet.	—	—	—	—	—	—	81·5	9·45	9·05	0	0	0	—	—	—	—	—	—
10	Musgrave Atlas Mills, Bolton.	Lancashire boiler	18 tons of coal a week of 60 hours.	—	—	—	—	—	—	81·8	8·65	9·55	0	0	0	80·75	12·7	6·55	0	0	0
11	Musgrave Atlas Mills, Bolton.	" "	18 tons of coal a week of 60 hours.	—	—	—	—	—	—	81·25	10·70	8·05	0		0	—	—	—	—	—	—
12	N.E. Steel Co., Middlesbro'	Lancashire boiler	Durham coal	82·95	3·5	13·25	0·05	0·25	0	—	—	—	—	—	—	80·75	8·4	10·85	0	0	0
13	Tharsis Copper Co., Newcastle.	Lancashire boiler	Small coal. Before and after stoking.	80·5	14·3	5·2	0	0	0	—	—	—	—	—	—	80·15	15·20	4·65	0	0	0
14	Newcastle Chemical Co., Salt Works.	Fire under salt pan	Small coal	—	—	—	—	—	—	—	—	—	—	—	—	79·55	18·45	2·0	0	0	0
15	Newcastle Chemical Co., Salt Works.	" "	"	—	—	—	—	—	—	—	—	—	—	—	—	79·75	18·40	1·85	0	0	0

Analyses of Chimney Gases—*continued.*

Number.	Name of Firm.	Description of Furnace.	Remarks.	Smoky.						Slight Smoke.						Clear.					
				N	O	CO_2	CO	CH_4	H	N	O	CO_2	CO	CH_4	H	N	O	CO_2	CO	CH_4	H
16	Friar's Goose Chemical Co.	Sulphate roaster furnace.	Small coal. Before and after firing.	82·42	2·15	14·85	0·25	0	0·33	—	—	—	—	—	—	82·75	2·4	14·85	0	0	0
17	Kurtz & Co., St. Helens -	Fire under caustic pot.	Before and after firing -	81·80	7·50	10·25	0·45	0	0	81·15	8·75	9·5	0·5	0·1	0	—	—	—	—	—	—
18	N.E. Steel Co., Middlesbro'	Heating furnace -	Durham coal - -	—	—	—	—	—	—	—	—	—	—	—	—	83·55	8·65	7·8	—	0	0
19	Newcastle Chemical Co. -	Fire under caustic pot.	Small coal. After firing -	81·95	4·45	10·35	2·35	0·75	0·15	—	—	—	—	—	—	—	—	—	—	—	—
20	Thos. Rayner, Northwich	Fire under salt pan	Four fires to pan - -	80·3	12·75	6·75	0·2	0	0	80·25	13·55	6·2	0	0	0	—	—	—	—	—	—
21	Sadler & Co., Middlesbro'	Fire under caustic pot.	Small coal. Before and after firing.	80·82	1·3	10·95	3·0	0·70	3·23	—	—	—	—	—	—	84·0	8·25	7·75	0	0	0
22	Tharsis Copper Co., Newcastle.	Calcining furnace -	Small coal. Before and after firing.	80·25	10·0	9·0	0·75	0	0	80·75	10·25	9·0	0	0	0	80·75	12·90	6·35	0	0	0
23	A. J. Thompson, Northwich.	Fire under salt pan	Small coal. Before and after firing.	80·2	16·3	3·5	0	0	0	—	—	—	—	—	—	80·0	17·0	3·0	0	0	0
24	Bass & Co., Burton -	Lownd's hollow bridges.	Before and after firing -	—	—	—	—	—	—	80·9	8·35	9·85	0	0	0	80·35	12·8	6·85	0	0	0
25	Dacca Twist Mills, Manchester.	Holden's hollow bars	Before and after firing -	—	—	—	—	—	—	80·85	8·9	10·25	0	0	0	79·7	15·55	4·75	0	0	0
26	Dacca Twist Mills, Manchester.	" " -	" " - -	—	—	—	—	—	—	82·25	5·05	12·7	0	0	0	—	—	—	—	—	—
27	Eureka Salt Co., Northwich.	Higgins' patent blast draught.	Before and after firing - {	80·35	14·90	4·75	0	0	0	—	—	—	—	—	—	80·05	16·7	3·25	0	0	0
				80·25	16·40	3·35	0	0	0	—	—	—	—	—	—	79·95	16·55	3·5	0	0	0
28	J. C. Gamble & Son, St. Helens.	Sliding door to fire, open when stoking, and closing gradually (3 mins. to shut).	Before and after firing -	—	—	—	—	—	—	81·3	9·55	9·15	0	0	0	81·0	11·75	7·25	0	0	0
29	J. Schofield, Littleborough	Finch's furnace -	Ordinary condition. Large coal.	—	—	—	—	—	—	—	—	—	—	—	—	80·8	13·9	5·3	0	0	0

Analyses of Chimney Gases—*continued.*

Number.	Name of Firm.	Description of Furnace.	Remarks.	Smoky.						Slight Smoke.						Clear.					
				N	O	CO_2	CO	CH_4	H	N	O	CO_2	CO	CH_4	H	N	O	CO_2	CO	CH_4	H
30	J. Schofield, Littleborough	Finch's furnace -	Ordinary condition.	—	—	—	—	—	—	—	—	—	—	—	—	80·75	13·5	5·75	0	0	0
31	J. & E. Stott, Flixton -	Harlow's hollow bars.	Large coal. After stoking - -	—	—	—	—	—	—	81·0	10·75	8·25	0	0	0	—	—	—	—	—	—
32	,, ,, -	Harlow's hollow bars.	Before stoking - -	—	—	—	—	—	—	79·5	15·25	5·25	0	0	0	—	—	—	—	—	—
33	Sutton Lodge Chemical Co., St. Helens.	Fire under caustic pot.	Slanting fire bars. Do. -	79·93	11·1	7·05	1·35	0·45	0·12	—	—	—	—	—	—	80·75	13·65	5·6	0	0	0
34	Sutton Lodge Chemical Co., St. Helens.	Fire under caustic pot.	,, ,, -	—	—	—	—	—	—	—	—	—	—	—	—	80·3	15·05	4·65	0	0	0
35	Talbot Mills, Manchester	Split bridge, 3 boilers.	Before and after stoking -	—	—	—	—	—	—	80·25	14·6	5·15	0	0	0	79·75	16·0	4·25	0	0	0
36	Wardle & Brown, Bolton	Split bridge, inlet of air controlled by door.	18 tons coal a week. No smoke usually.	79·6	7·00	8·75	3·25	0·40	1·00	81·25	8·4	10·35	0	0	0	80·85	11·4	7·75	0	0	0
			Mechanical Stokers.																		
37	John Bayley & Son, Bolton.	Vicars stoker - -	$3\frac{1}{2}$ tons coal in 10 hours -	—	—	—	—	—	—	—	—	—	—	—	—	80·75	12·0	7·25	0	0	0
38	Canon Bros., Bolton -	Jukes stoker -	22 tons a week of 60 hours	—	—	—	—	—	—	80·1	14·65	5·25	0	0	0	—	—	—	—	—	—
39	Crook & Son, Bolton -	Sinclair stoker -		—	—	—	—	—	—	80·75	11·0	8·25	0	0	0	—	—	—	—	—	—
40	Crosses and Winkworth, Bolton.	Bennis stoker - -	20 tons coal a week - -	—	—	—	—	—	—	80·25	13·9	5·85	0	0	0	80·35	14·4	5·25	0	0	0
41	Farnworth Bridge, Bolton	Cass stoker - -	Fire in ordinary condition	—	—	—	—	—	—	—	—	—	—	—	—	80·25	13·50	6·25	0	0	0
42	,, ,,	,, ,, - -	- - - -	—	—	—	—	—	—	—	—	—	—	—	—	81·10	7·35	11·65	0	0	0
43	,, ,,	,, ,, - -	- - - -	—	—	—	—	—	—	—	—	—	—	—	—	80·70	12·15	7·15	0	0	0

ANALYSES OF CHIMNEY GASES—*continued.*

Number.	Name of Firm.	Description of Furnace.	Remarks.	Smoky.						Slight Smoke.						Clear.					
				N	O	CO_2	CO	CH_4	H	N	O	CO_2	CO	CH_4	H	N	O	CO_2	CO	CH_4	H
44	Gossage & Co., Widnes	Bennis stoker	Fire in ordinary condition	—	—	—	—	—	—	—	—	—	—	—	—	80·75	11·1	8·15	0	0	0
45	" "	Vicars stoker	" Temp. of flue gases 380° F	—	—	—	—	—	—	—	—	—	—	—	—	80·45	12·95	6·6	0	0	0
46	Musgrave, Bolton	Vicars stoker	18 tons coal a week of 60 hours.	—	—	—	—	—	—	—	—	—	—	—	—	79·7	19·3	1·0	0	0	0
47	" "	Hodgkinson's sprinklers.	Ordinary condition	—	—	—	—	—	—	—	—	—	—	—	—	80·35	16·4	3·25	0	0	0
48	Peter Spence & Son, Manchester.	McDougal stoker	" "	—	—	—	—	—	—	—	—	—	—	—	—	80·35	12·45	7·2	0	0	0
49	Brunner, Mond, & Co., Northwich.	Lancashire boiler	Fired by producer gas	—	—	—	—	—	—	—	—	—	—	—	—	82·00	0·45	17·30	0	0·25	0
50	Outram, Greetland	" "	Fired by Thwaites' producer gas.	—	—	—	—	—	—	—	—	—	—	—	—	80·60	11·15	8·25	0	0	0
51	" "	" "	" " "	—	—	—	—	—	—	—	—	—	—	—	—	80·00	13·00	7·00	0	0	0
52	" "	" "	" " "	—	—	—	—	—	—	—	—	—	—	—	—	79·80	13·70	6·50	0	0	0

exception was where gaseous fuel was used; here the balance was very nearly maintained, neither ogygen nor combustible gases being in excess.

In order to avoid the evils inherent to hand-stoking, to render the supply of coal more constant, and to keep the fire in a more uniform condition, many mechanical appliances have been adopted. In some of these the coal is continually thrown or sprinkled on to the fire in small quantities, in others it is pushed in at the front and worked back by movement of the bars till the clinkers are discharged under the bridge. A great many patents have been taken out for the various modifications of these machines, and for methods of conducting the combustion of coal in furnaces economically without the production of smoke. Some of these appliances are expensive to erect, and some have proved very expensive in use, the cost of maintenance being excessive, while some, on the other hand, effect a saving of labour and of fuel. In order, therefore, to ascertain the relative merits of all the various appliances offered with a view to economise fuel, and to prevent the discharge of smoke, a co-operative manufacturers' association* has been formed for testing practically all the principal smoke-preventing appliances found in general use, reporting on their first cost, the cost for repairs, and the comsumption of fuel in proportion both to the work done and to the amount of boiler space provided. When this report is published it will afford a valuable guide to all those manufacturers who desire to prevent the discharge of black smoke from their chimneys and to obtain the utmost efficiency from their boilers and from the fuel they consume.

One method now largely employed for effecting the complete combustion of fuel, and for preventing the discharge of black smoke, is that of converting the coal into gas and employing it in the furnace in place of solid fuel. This is done by burning the coal in a gas-producer. A limited portion of air only is admitted, so that the fue is carried off as a gas consisting of a mixture of carbon monoxide and hydrocarbons. If steam is admitted, it is decomposed by the incandescent carbon. In this operation of gas production about one-third the heat of the fuel is lost at the producer, and unless some corresponding advantage sufficient to compensate for this expenditure can be gained, the process is not economical. In many cases, convenience of application and the opportunity of saving in regenerators some of the heat justify the initial loss; in great measure it may also be recouped by so treating the gas as to separate the tar and ammonia formed in its generation. Where this is done, or where in any other way the employment of gas can be made economical, its use as a fuel is greatly to be desired as a means of preventing the emission of black smoke. Its use is particularly to be recommended in furnace fires, where a reducing atmosphere is needed, as in iron-heating furnaces. In such cases the gas may be made largely to consist of carbon monoxide and hydrogen; these, being kept in

* The Secretary of the Association is Mr. Fred. Scott, 44, John Dalton Street, Manchester.

excess of the air supplied for combustion, will afford a reducing atmosphere in the furnace, and will burn as it escapes either through the door or the chimney with a smokeless flame.

It may be confidently asserted that by the observance of the principles here laid down, and by the adoption of appliances now in frequent use, the economical use of bituminous coal as a fuel may be conducted without the discharge of black smoke.

House Smoke.—Thus far attention has been drawn to the prevention of black smoke from manufacturing operations. In many of our densely-peopled cities, however, the house chimneys contribute more to the pollution of the air than do those of factory furnaces.

Many attempts have been made by introducing close stoves or modifications of our fire-grates to prevent the emission of smoke, but our preference for the open fire, in which a flaming coal is burnt, is so determined that it would seem that smoke is inevitable. Sir Douglas Galton has done good service by devising a form of open grate in which a supply of air is so introduced as to assist greatly in the combustion of the smoke that would otherwise have escaped. Still there *is* smoke, and that, coming as it does from a thousand chimneys, forms a mighty cloud and an enormous pollution of the atmosphere. One further suggestion may, however, perhaps be made, for at any rate largely diminishing this discharge of smoke while still retaining the open fire.

Let a hot-air stove, burning coke or anthracite, be placed in the basement of the house, and a copious supply of warm, but not overheated, air be thrown into the passages and rooms. This has the effect of adding so much to the general comfort of the house that the demand on the separate fires is greatly diminished, less coal is burnt in them, and less smoke is therefore given off. The air, before coming to the stove to be warmed, should be led through a large filter-sheet of cotton wool or other fibrous matter, to collect the dust and smut. It is then not likely to convey the burnt or charred smell which arises from the scorching of the small pieces of fibre and organic matter generally to be found floating in it. As every chimney from the open fires is carrying up a large quantity of air, this air must be supplied to the house through some channel. Usually this is done by the leakages at window or door, causing unpleasant draughts; or at night, when all is close shut, this supply of air enters down the unused chimneys, bringing the damp and cold air from outside into the bedrooms, and with it a strong and most unwholesome smell of soot. All these evils are avoided by the admission of a copious stream of warmed filtered air into the house through a channel properly provided for it.

The use of gas as a smokeless fuel is largely to be recommended as a means of diminishing the production of smoke; its employment for cooking, heating of water for baths, &c. cannot be too warmly advocated, and also its largely-extended use for heating our rooms, while the general warmth of the house is maintained by a central hot-air stove.

A supply of cheap gas, and its liberal use as fuel in dwelling-houses, together with the adoption of coke-fed hot-air stoves in the

basement of houses, will, I think, be found the most effectual cure for the great plague of town smoke. Where this system is adopted, the present open fires, to which we are so much attached, may remain, but their use will be greatly diminished, while our comfort both in and out of our houses will be largely increased. Seeing that by this system the carrying of coals about the house, the removal of ashes, and the daily cleaning of fire-grates would be much lessened, the use of gas as a fuel can be recommended for its economy as well as for its cleanliness.

DISCUSSION.

The Mayor of Manchester (**Alderman John Mark**) said that there was now very much less smoke in Manchester than was the case some years ago. Many efforts had been made to improve matters, but improvement had been effected mainly in manufactories. The Manchester authorities had offered special facilities to the inhabitants to burn gas for heating purposes.

Mr. Courtney (Chelsea) stated that he had in use a hand-fired furnace in which, by careful attention to the relative quantities of air and coal employed, no smoke was produced; and invited members of the section to inspect it.

Demonstration of the possibility of removing the Smoke of Fires from the Air of Towns and of using it for Disinfecting Sewers.

BY

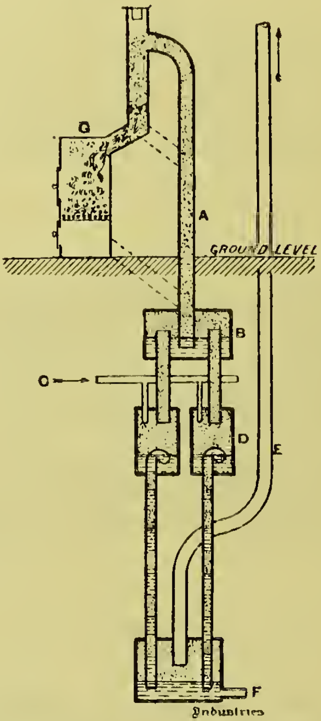
Dr. Sheridan Delépine and Mr. Alfred B. Gomess.

By means of a small quantity of water falling from a moderate height (a few feet) it is possible to produce a displacement of a large amount of air and to divert the smoke of a fire from a chimney into a system of pipes running in any direction.

By a very simple combination of channels and chambers the most fluid parts of the sewage may be used for the purpose of displacing the smoke and causing it to mix with the sewage (wherever a proper fall can be obtained by taking advantage of a natural disposition of the ground, or by raising the sewage artificially). Any supply of water could also be used for the same purpose.

A working model was shown by means of which the smoke of a fire could be carried by, and mixed with, water to any distance from and to any level below that of the fire.

The following is a brief description of the apparatus as shown in model form in the accompanying illustration.



SECTIONAL VIEW OF MODEL.

A stove G, in which turpentine is burnt, serves as the source of smoke, the stove chimney being capped so that no smoke can escape in the ordinary way. From the stove a descending flue A, communicating with the chimney and ending in a valve B, leads to the sewer. The object of the valve is to prevent any regurgitation of sewer gases when the apparatus is not at work. A number of jet pumps or exhausters D are connected with the flue or valve in such a way that a large amount of air can be displaced under low pressure by a small amount of water. The water pumps used have been specially devised for this purpose by Dr. Sheridan Delépine, and are based on the mode of action of intermittent siphons. The construction of the pump is such that a fall of only a few inches of water is sufficient to ensure a rapid removal of the smoke-laden atmosphere, and the authors point out that the same water can be used again and again provided the difference in level between one set of pumps and the other is at least 4 ft. or 5 ft. Owing to the difference of level existing between the various parts of a system of sewers, it would be possible to use filtered sewage as a source of power, and thus introduce at the same time into the sewage some of the numerous disinfectant products contained in the smoke. In this

way decomposition of the sewage would be retarded, and its value as a manure would be increased.

[NOTE.—The apparatus exhibited and represented diagrammatically above was only an experimental one, the object being to show the principle of the method as schematically as possible. E represents a ventilating shaft, and F an outlet (for the water charged with soot and other products) connected with a separating chamber, of which a series has to be used.]

Wednesday, 12th August 1891.

The President, Sir H. ROSCOE, in the Chair.

The Chemical Treatment of Sewage, with special reference to the Treatment of the London Sewage.*

BY

A. DUPRÉ, Ph.D., F.R.S.

Sewage must, in the first place, be looked upon as a material to be got rid of without injury to the population, and with the minimum amount of nuisance, without reference to any profit that might be derived from it.

The solution of the problem as to which is the best method of sewage disposal is so complicated, owing to the different conditions obtaining in different towns, that no general plan can, or should, be laid down, but each case must be treated on its own merits.

Of two plans for the disposal of sewage, both equally effective, the cheaper should be adopted.

CHEMICAL TREATMENT.—Many processes for the chemical treatment of sewage have been brought forward; but, excluding the proposed electrical treatment of sewage, which has not yet passed its period of probation, and the action of permanganate, of which more later, they may all be said to depend on the action of certain salts of alumina and iron, with or without the use of caustic lime.

The main effect of such chemical treatment is the more or less complete clarification of sewage, together with the removal of a certain proportion, generally a small one, of matters held in solution.

The character of the effluent, in some measure, depends on the condition of the sewage. Fresh sewage yields a better effluent than foul sewage; consequent necessity of some further treatment.

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* This is the Abstract of a Paper which, owing to the Author's illness, could not be prepared for the Congress in full.

London Sewage.—*Difficulty of the Problem.*—Excessive volume of sewage to be dealt with. Size of area whence it comes, and consequent length of sewers, and foulness of sewage when it arrives at the outfalls. *System of London Sewerage.*—Collecting sewage proper and the rain-water in one system of sewers. Unsuitability of land in the neighbourhood for sewage-farming, distance from the sea. *Solution of the Problem,* as attempted by the late Metropolitan Board of Works. Chemical processes clarify, but do not remove much dissolved matter. Evil effects of excess of chemicals used. Consequent use of minimum amount of chemicals capable of clarifying the sewage. The clarified sewage deodorised by manganate and sulphuric acid. Resulting effluent, inodorous and nearly clear, discharged into the river mainly during ebb tide. Portion of the river should be regarded as a sewage-farm, does its work in smaller area, as effectively and with far less nuisance than a sewage-farm proper. Destruction of sewage in river and on farm due to living organisms, but oxygen necessary. The River Thames capable of dealing effectively with the effluent. Consideration shows that the river will be adequate to deal with effluent for some time to come. This period can be prolonged by the proper use of manganate. Beneficial effects on river of proposed treatment of sewage greater than the mere removal of suspended matter would seem to indicate. Destruction of dissolved matter goes on more or less all the year round. Destruction of suspended matter greatly retarded during cold weather, and nearly the whole year's production has to be destroyed during summer.

Summary.—The plan adopted is far the cheapest. It will dispose of the London sewage, without nuisance, until London has increased to from 8,000,000 to 10,000,000 inhabitants.

When that time arrives, only the sewage in excess of the quantity capable of being dealt with by the river, will have to be differently dealt with, with a corresponding reduction in cost compared with that which would be necessary if the entire sewage had to be so dealt with.

Capital, once expended, fixes the minimum yearly expenditure; outlay for chemicals can be increased or diminished according to circumstances; hence annual cost can be controlled.

Chemical and Physical Processes employed in the Treatment of Sewage.

BY

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The few remarks I have to make in introducing this subject will refer exclusively to water-carried sewage.

The character and composition of such sewage need not be dwelt upon, and the causes of its variation in character, &c. in different towns

requires only to be alluded to briefly. In the majority of towns the sewers convey domestic sewage, manufacturing refuse, and rain and storm water. The domestic sewage may or may not include human excrement. The manufacturing refuse will vary in character with the staple industry. The rain and storm water chiefly affects the sewage by increasing its volume in proportion to the rainfall, and this occurs at irregular intervals. To avoid this disturbing element of variation in quantity, many towns recently sewered have adopted the "separate" system of sewerage, conveying as much of the rainfall as possible directly into the running streams. Where this has been done, the amount of sewage to be disposed of daily is a fairly constant quantity, and the difficulties in treating the sewage are reduced to a minimum.

The great variation in the strength and character of the sewage in different localities renders it impossible to devise any one system of treatment which shall be universally applicable. Moreover, the degree of purification required is not constant. Where the sewage can, with safety, be cast into the sea, or into the estuary of a tidal river, purification need not be nearly so complete as when its only outlet is into a stream which, a little lower down, furnishes the water-supply to the towns and villages on its banks.

The deleterious matters contained in water-borne sewage are chiefly "organic," and of two kinds, soluble and insoluble, the former being, of course, in solution, and the latter in suspension. The insoluble portion, again, may be divided into (*a*) living organisms: bacteria, &c.; and (*b*) dead organic matter.

The relative importance of these constituents of sewage in reference to its purification is a subject which admits of considerable diversity of opinion. It will, however, be admitted by all that where the effluent must pass into a stream furnishing the water-supply to communities lower down along its course, no system of treatment will be satisfactory which does not remove entirely any specific organisms which may be present, and all the suspended impurities. The dissolved organic matters also must be reduced to a minimum by precipitation, oxidation, or in some other way. To effect this a combination of processes is usually resorted to, physical and chemical. A classification of these is a somewhat difficult matter, inasmuch as certain groups overlap the others; but the following will, probably, answer every purpose:—

1. Subsidence—
   - (*a*.) With complete rest.
   - (*b*.) During slow, but continuous, flow.
2. Mechanical straining and filtration.
3. Chemical filtration; or percolation through materials exerting some chemical, or catalytic, action on the organic matters.
4. Precipitation by the addition of one or more chemicals. These may be—
   - (*a*.) Soluble, as the salts of iron and alumina; or
   - (*b*.) Insoluble, as clay, magnetic oxide of iron, and the various kinds of charcoal.
5. Electrolysis, or purification by electrical treatment.

6. Oxidation and destruction of the organic matter by addition of chemicals.
7. Sterilization and disinfection by the destruction of micro-organisms, and the arrest of putrefaction.
8. Nitrification, or the destruction of the organic matters by the action of the nitrifying organisms found in surface soils.
9. Irrigation, or the utilization of the organic matter as food for growing crops.

In exceptional cases only is any one of these processes alone found to yield sufficiently satisfactory results. To attain such results, two or more of them must be used in combination or in succession. Thus, after the addition of chemicals to effect precipitation, the precipitate must be removed either by subsidence or filtration, or by both, and the effluent may even require further purification, either by percolating through land for "nitrification," or through specially prepared chemical filters. Even where the sewage is passed onto the land, a preliminary straining or filtration, or a partial clarification by subsidence, is frequently resorted to; where it is not, the land itself will act as a mechanical as well as a chemical filter.

The various groups of processes may now be referred to *seriatim.*

1. *Subsidence.*—Practically, this is only applicable as a preliminary to some other mode of treatment, or after such treatment, or when the sewage is turned directly into the sea or a tidal river. When sewage is allowed to stand, the grit brought down from the roads after rain settles somewhat rapidly, carrying with it a little of the insoluble organic impurity. The remainder of the suspended matter falls so slowly that active putrefaction commences long before clarification is complete. After the addition of certain precipitating agents, the suspended particles fall more or less rapidly. Most rapid clarification takes place in sewage which has been rendered strongly alkaline by the addition of lime, and in which, by a judicious selection of chemicals and proper agitation, the precipitate is flocculent in character. When magnesia salts are added, a much smaller amount of lime is required to produce large flocculi. In other cases, insoluble substances, such as clay, ground coke, &c. are added, and, in subsiding, the particles carry down with them more or less of the previously suspended matter. The rapidity with which the insoluble matters subside is of importance chiefly as affecting the size of the tanks necessary for treating a given quantity of sewage. Subsidence takes place most rapidly, *cæteris paribus*, when the fluid is allowed complete rest. The slowest of motions along a tank retards the process. Very frequently such tanks are provided with screens, floats, dividing walls, &c., which, from their arrangement, retard still further, instead of accelerating, the deposition of the suspended matters.

2. *Mechanical Straining and Filtration.*—Straining, of course, is only intended to remove the coarser matters which are washed down the sewers. Filtration, on the other hand, attempts the removal of all suspended impurities. Sewage, unless previously treated by some chemical or other process, filters very slowly, and rapidly clogs up the pores in

the material used, whether this be sand, or charcoal, or earth. Most filtering materials, however insoluble in character, seem to be capable for a time of removing, not only the suspended matters, but a portion of the dissolved organic matter also. With the ordinary sand and gravel filter this action is slight and soon disappears, and mere filtration through such materials does nothing more than clarify the sewage. The number of micro-organisms may be enormously reduced, but inasmuch as the soluble constituents of the sewage are unaffected, multiplication of the remaining organisms occurs with increased rapidity. No practicable system of sewage filtration can be relied upon to remove specific organisms or to sterilize the fluid. For the above reasons, filtration, *i.e.*, mechanical filtration, can only be considered of real service as an adjunct to some other process.

3. *Chemical Filtration.*—This term is employed, for lack of a better, to the filtration of sewage through materials of an insoluble nature, which, however, possess the power of withdrawing from solution, or otherwise of destroying, certain of the organic constituents. Animal charcoal is the type of such material, and the decolourization of a solution of caramel and the removal of alkaloidal bodies from solution when the fluids are passed through it are typical of the action of such a filter. The Rivers Pollution Commissioners found that filtration through either sand or a mixture of chalk and sand could purify a certain amount of sewage, and that the process was "essentially one of oxidation, the "organic matter being to a large extent converted into carbonic acid, "water, and nitric acid." Certain compounds of iron and manganese possess this power of causing oxidation in a very much higher degree than sand or chalk. Besides this action, however, substances like charcoal act by withdrawing certain organic matters from solution, by absorption or occlusion without at the same time necessarily causing their destruction. This action, however, is limited, and of little practical utility in sewage purification. Spongy iron, magnetic carbide of iron and polarite (which consists chiefly of magnetic oxide of iron) are the materials commonly employed in chemical filtration. When the filtration is intermittent, so as to allow of frequent aeration of the filtering medium, the action continues for a considerable period. Experiments which have recently been made with polarite filter beds seem to indicate that this substance retains its oxidizing powers for an indefinite period. When sewage has been previously treated either by subsidence or by some process of precipitation so as to remove most of the suspended matters, and as much as possible of the dissolved organic impurities, the clarified sewage passes rapidly through the polarite filter, and if the latter is properly constructed, a very considerable proportion of the remainder of the organic matter is oxidised, and the effluent attains a standard of purity "greatly exceeding that prescribed by the Rivers Pollution Commissioners." This process is now at work at Acton, near London, and at Swinton, near Manchester, and appears to give most satisfactory results.

It is highly probable that this combination of processes—precipitation, subsidence, and chemical filtration—will in the near future be regarded with the greatest favour.

4. *Precipitation Processes.*—These processes are so well known that it will be unnecessary for me to do more than indicate the principles upon which they are based. Precipitating agents are added for two purposes—to cause rapid precipitation of suspended impurities, and to remove as large a portion as possible of the impurities in solution. The number of materials and of combinations of materials which have been recommended or patented for purifying sewage by precipitation is very great. Few of them, however, have proved of practical utility. The salts of iron and of aluminium, with or without the addition of lime, are the chemicals now most frequently employed, and these yield the most satisfactory results. In very few instances, however, is an effluent produced of sufficiently high standard to permit of its being cast in large volume into a running stream. To effect this, further purification by chemical filtration, or sterilization, or oxidation must be resorted to. The London sewage, for example, after being precipitated is, during the hot weather, further dosed with an acid solution of potassium permanganate to oxidize the more putrescible constituents which have escaped precipitation. There is, however, another important series of precipitation processes which aims at the further purification of the sewage by the absorption or occlusion or destruction by oxidation or reduction of the organic matter which would otherwise remain in solution. The best known of these processes is probably that designated the ABC, from the initials of the three principal substances—alum, blood, and clay—used as precipitation agents. Here the blood, charcoal, and clay added are said to act as absorbents, and to carry down with them certain substances which would not be removed by the aluminium salts alone. Drs. Dewar and Tidy, who recently reported on this process, state " that it precipitates " 60 per cent. of the organic matter in solution, and of the residue left " in the effluent at least two-thirds are non-albuminous, and, therefore, " of a nature less liable to putrefactive and other changes." The International Sewage Purification Company treat their sewage with " ferrozone " (a fancy name for a mixture of magnetic oxide of iron with salts of iron, alumina, and magnesia). A process of oxidation is said to accompany that of precipitation, but the effluent is further purified by being passed through a polarite filter bed.

Mr. Hanson uses as precipitants a mixture of lime and black ash-waste. The latter is said to contain a considerable amount of sulphites and hyposulphites, which, from their powerful reducing action, greatly improve the character of the effluent.

5. *Electrical Treatment.*—Quite recently Mr. Webster has patented a process for purifying sewage by electricity. The sewage is caused to travel along a trough in which are placed iron plates connected with the positive and negative terminals of a powerful dynamo. Water is decomposed together with, so it is stated, a certain portion of the sodium chloride present in all sewage. Iron enters into solution, and then precipitates a portion of the organic matter from solution, at the same time carrying down with it the suspended matters. A further portion of the organic matter is supposed to be oxidised by the nascent oxygen and chlorine oxides produced. The amount of sludge formed is said to be smaller than in any precipitation process, and

the effluent to be purer, rendering further treatment by filtration unnecessary "except to remove sentimental objections." The process has been experimentally tested at Crossness (with the London sewage) and at Salford, and the experts employed have given very favourable reports in both places. Extended series of experiments on a much larger scale are, however, necessary to convince the sceptical that this is other than a roundabout way of producing a soluble iron salt to act as the precipitating and purifying agent.

6. *Oxidation of Organic Matters by Chemical Agents.*—Attempts have frequently been made to destroy the organic matter in sewage by oxidising agents such as potassium permanganate, but the success hitherto has either been limited, or the expense prohibitive. Patents have also been taken out for oxidising sewage by forcing air through it. Something more, however, than mere contact with air seems to be necessary for the oxidation of the organic matter. From experiments made on a small scale in my laboratory, I found that a current of air passed through a sample of sewage for three hours, possibly the maximum of time during which sewage could be retained in the works for such treatment, produced practically no effect upon it. The suspended matter did not afterwards subside more rapidly, neither was the dissolved organic matter reduced in amount or apparently altered in quality.

7. *Sterilization and Disinfection.*—In this group of processes the removal of dead organic matter, whether in suspension or in solution, is only a secondary consideration, the object being to destroy, as far as possible, all micro-organisms, and so to prevent or retard putrefactive changes. Most of these processes are used but temporarily to prevent nuisances arising in the hot weather. Chloride of lime, carbolic acid, permanganate of potash, and many other substances have been recommended for this purpose. The practical utility of any such process, except as a temporary expedient, is more than doubtful. Unless sterilization is complete the surviving organisms will rapidly multiply, and even where the effluent is absolutely sterile it may contain a large amount of organic matter which, when poured into a river, will serve as pabulum for the organisms in the river water and cause their abundant increase. No doubt it would be a great point gained were we able to prevent specific bacteria from entering our streams with the sewage, but its importance is often greatly exaggerated. The water of streams exposed continually to the action of air and light does not seem to be a favourite habitation of such organisms, and it is probably much more important to avoid polluting the streams so as to render them tolerant of such visitors than to merely attempt to keep them out at those points where the processes can be adopted. A process which, whilst removing the maximum of organic matter from the sewage, would render it also sterile and otherwise innocuous would be the perfection of sewage treatment. Sterilization appears to be most completely effected by the "Amines" process, consisting essentially in the treatment of the sewage with a mixture of herring brine and milk of lime. The brine or some body formed by the action of the lime thereon

acts as the bactericide, and the lime as a precipitant. The effluent resulting from this treatment, though sterile, is alkaline, and contains much organic impurity in solution.

Some time ago a metropolitan committee recommended the addition of disinfectants to the sewage in the house drains and small sewers to prevent putrefaction and evolution of gases. From time to time patents have been taken out and suggestions made to enable each house to treat its own sewage before casting it into the sewer. Such arrangements may prove of service in isolated buildings with their own system of sewers, unconnected with any other system, but in other cases the advantages are problematical.

8. *Nitrification.*—In the process known as "intermittent downward filtration through land" the sewage is purified (*a*) by mechanical filtration, (*b*) by chemical action of the oxygen occluded in the soil, and (*c*) by the action of the living nitrifying organisms found in all fertile surface soil. On all hands it is now conceded that it is far preferable to filter the sewage mechanically or to remove suspended matter by precipitating agents before passing it through the soil. As a mechanical filter the pores of the soil more or less rapidly become choked, and the rate of filtration is in proportion reduced, aeration is rendered more difficult and less perfect, and the oxidizing action diminishes in energy. Properly prepared soils possess in a most marked degree the property of purifying sewage. The action is essentially one of oxidation effected in part by the oxygen occluded in the pores of the soil and in part by the action of certain organisms which occur in great abundance in such soils. The relative importance of these actions in the treatment of sewage is a matter concerning which much uncertainty exists, but the balance of evidence is probably in favour of the organisms discharging the most important functions. Müntz, in a recent communication to the French Academy, states that he regards "the work of the "nitrifying organisms as confined to the oxidation of nitrogenous "matter to nitrites," the further change of nitrites into nitrates being effected by the action of the oxygen and carbonic acid in the soil. Warrington, as a result of his recent researches, includes the following in his summary :—

1. The nitrification occurring in a mass of aerated soil is purely nitric in character. Soil readily converts a solution of nitrite into nitrate.
2. Pasture soil produces nitrites more readily than arable soil.
3. A clay subsoil, down to four feet from the surface was found to produce nitrates.
4. The nitrification effected by soil is thus explained. It is performed by two organisms, one of which oxidises ammonia to nitrites, while the other oxidises nitrites to nitrates.
5. In soil, the nitric organism is equally as active as the nitrous.
6. The nitrous organism requires no organic matter for its nutrition.
7. The presence of ammonia is a great hindrance to the action of the nitric organism.

From the above results it appears probable that these organisms act almost exclusively on the ammonia of the sewage, oxidizing it to nitric acid. With too concentrated a sewage the influence of the nitric organisms may be diminished, and nitrites appear in the effluent. The nitrous organism is, however, capable of producing nitrous acid in solutions of asparagine, milk, urine, and urea; the last mentioned being the most difficult to attack. Further researches in this direction are required to ascertain by what means the organic matter is decomposed in the soil into ammonia and carbonic acid. Probably, as the *micrococcus ureæ* splits up urea, so other similar organisms may be able to decompose the more highly complex nitrogenous constituents of sewage.

9. *Utilization of Sewage as Food for growing Crops, or Broad Irrigation.*—For the first time I have had to make use of the word utilization, for by broad irrigation only can raw sewage be put to any practical use. In many of the processes enumerated there is produced a sludge which innumerable attempts have been made to convert into a manure of sufficiently high fertilising power to command a sale in the market. None of these, however, have met with any great measure of success.

Whilst nitrification or intermittent downward filtration through land merely oxidises certain constituents of the sewage to nitrates, and the latter run to waste, in broad irrigation a certain portion of the nitrate so produced is assimilated by the crops grown on the farm. The proportion of the nitrogen so utilised varies considerably, not only on different farms, but on the same farm from time to time. Yet if only half the nitrogen can be saved, it is a larger proportion by far than can be abstracted and utilised by any other process.

Broad irrigation, as at present conducted however, does not seem to offer a final solution of the problem, how best to dispose of our sewage? In a few instances only has sewage-farming proved a success. With exceptionally favourable soil and situation such a farm may continue to be remunerative for many years, but it seems very probable that there is a limit to this period. Yet such a farm, even if it does not pay expenses, may still prove much more economical than a process of sewage treatment requiring costly plant and machinery, and a large annual expenditure in labour and in chemicals, and producing nothing but an unsaleable manure.

Apart, however, from the question of expense, many objections have been raised to sewage farms on sanitary grounds. And here again, as with everything else connected with this subject, opinions diametrically opposed are held and expressed. By one party it is said to give rise to offensive and injurious emanations, to pollute the subsoil water, and to favour the distribution of the ova of entozoa; whilst others assert that in a properly-conducted farm there are no such emanations, that the subsoil water is not polluted more than by the application of any other manure, and lastly, that there is no shadow of proof that disease attributable to entozoa has ever been due to the consumption of vegetable or fruit from a sewage farm.

I have now mentioned all the processes of practical value in sewage treatment, but there are many others, such as those necessitating distillation, freezing, &c., which are so obviously impracticable that it would be a waste of time even to enumerate them.

Do any of the processes mentioned, or any combination of such processes, enable us to get rid of our sewage in such a way as to give rise to no nuisance, cause no danger to health, and this at a cost sufficiently reasonable, considering the importance of attaining such results? This is the question I would submit to the Members of this Congress.

The Duty of a Locality to Utilise the Nitrogenous Matter in its Sewage for the Benefit of the Nation.

BY

Alfred Carpenter, M.D.

The object of this paper is to show that localities have duties to the nation to which they belong. It is not a sound argument to assert that the performance of these duties may have an apparently adverse result for the time being, by causing considerable expense. Some other course may possibly save the local authority an immediate capital expenditure, but if that course be persevered in, it may lead to much loss and mischief to the nation. The transportation of felons (the refuse of society) to the other side of the world, appeared for the time to save this country much trouble, but perseverance in that course would have involved disastrous results. In the case of sewage refuse, when the land is deprived of its natural requirement agricultural exhaustion ensues. It is one of the laws of nature that plant life is required for the support of animal existence; and the converse is also true, that growth of animal matter is necessary for the continued development of vegetable produce. The fruits of the earth, which are especially wanted for human subsistence, require for their rapid growth the continued or occasional application of ammonia, and various other salts, in addition to carbonic acid. As the density of population increases, the safety of the people requires that the land should have greater and more rapid powers of reproduction, and nature has not been regardless of this postulate. It is quite possible for a thickly peopled district to provide food for all its inhabitants without importing food stuffs. France, Holland, and Belgium, and more especially China, India, and Japan, are instances in point. It is true that famines have arisen, as the result of war or of extreme meteorological conditions, but the fact remains, that excluding these influences, the land has grown, and can grow, produce sufficient to support a densely peopled district. This has been brought about by the careful application of the excreta of the people to the soil itself, and a high

state of cultivation has procured large crops for the use of the inhabitants, while at the same time they have been preserved from the incidence of pestilence.

In consequence of the increase of wealth, and from other causes, such as the necessity for protection against the inroads of barbarians, or when a feudal baron had to protect himself against his next neighbour, people surrounded themselves with high walls, giving up in this country the habits of their Celtic and Saxon ancestors, who had wiser plans for the disposal of human excreta than their Norman successors. Human refuse then began to be stored in pits and cesspools, by which the subsoil in the towns and their immediate neighbourhood was polluted, and the progress of epidemics assisted whenever the meteorological conditions required for their manifestation arose.

The earliest hygienic indications which are found on record are in the Bible. Moses, the great Hebrew law-giver, ordered that human excreta should be conveyed to the earth, without the camp, and after the settlement in the land of Canaan, without the city, and all polluted articles, either of clothing or anything else, well washed with water. This law, established by a despotic authority, involved two points, 1st, the agricultural use of human excreta and its immediate conveyance to the soil; and 2ndly, the absolute necessity of an abundant supply of water.

As cultivation of the soil was the main source of wealth to the Hebrews, they soon became wealthy, and with riches came indolence and neglect of the laws laid down by Moses. They allowed their dwellings to be polluted, and prepared the way for their own overthrow by agents styled in Holy Writ "the armies of the living God." That is to say, the murrain among their cattle, the blasting, or blight, and mildew upon vegetation, with the palmer worm, the canker worm, and the caterpillar. These were clearly the disease germs which have only been scientifically demonstrated in recent years. It has been proved that their powers of multiplication are promoted by soil, air, and water polluted by human excrement, and when these pollutions are prohibited by authority, and their causes prevented, the locality which expends the necessary capital is ultimately repaid a thousandfold.

Coming to our own time, I venture to assert that a rate of a shilling in the pound, if judiciously dealt with, may be incurred with the certainty that its value will come back again. It is necessary that this expenditure should be general throughout the country, in order that complete results may be obtained. The law in this country has now decided that one locality shall not pollute another by casting its refuse outside its own boundary. It has come to pass that the cost of sanitary works, though great in the first application, has, in those districts where it has been judiciously applied, been productive of immense pecuniary benefit in the saving from sickness, incapacity from depreciated mental and muscular power, and early death. But while recognising the law as to cleanliness, the country generally has not awakened to the mischiefs which result from a neglect of the other portion of the ordinance. Human excreta is not as a rule conveyed to the soil, but impediments are placed in the way of its utilisation in this manner by many land-

owners and local authorities, with the result that agricultural produce is correspondingly diminished, and while population is increasing the people are rendered more and more dependent upon foreign countries for their food supplies. For more than 800 years human ordure has been mainly buried in the earth or passed away into the sea, or, worse still, into our running streams. By these means "the armies of the living God," the disease germs of modern times, have destroyed millions of people in the prime of life, and nature has been avenged for the neglect of sanitary law. Every human being discharges daily so many grains of phosphatic salts, and of material which becomes ammonia. Ammonia if not at once agriculturally utilised is reduced to its elements, carbonic acid nitrogen and water, thus losing 95 per cent. of its agricultural value, while the phosphates remain locked up in the cesspit, or pollute our water supplies. Phosphates are wanted for our wheat and other crops, and should be returned to the soil in the form in which they exist in human excreta. Had this been done, as ordered by our earliest authority on hygienic law, the constant re-application of the salts would have reacted, on the principle of small profits and quick returns, to the immense advantage of the people of the land.

There are several denunciations in Holy Writ, usually omitted in our public services, against those who pollute the walls of the city by micturition. No one can pass along the streets of any town or village in the kingdom, after 10 o'clock at night, and especially after the public-house closing hour, without witnessing the continuance of this act in our own time. I cannot exaggerate the evil, or say too much to draw the attention of local authorities to the mischiefs which result from the continuance in our cities, towns, and villages, of this indecent habit. Its denunciation in Scripture is not, in my opinion (as generally supposed), intended to indicate a judgment upon the people at large, but for the purpose of pointing out a breach of sanitary law in which the drunkard and the profligate indulged in Israel, as much as they do in Britain to-day. By this act the passer-by soon after may inhale a material capable of providing a forcing bed for disease germs, and allowing of the production of some of those forms of influenza and other catarrhal disorders which are so puzzling to the student in the etiology of epidemic disease, and are often the basis on which is established organic disease. These offences against decency are offences against the health of the community, and are taking from the nation a power to return to agriculture that which is required for the nation's welfare, for the larger part of the agricultural value of sewage is found in the urine. The denunciation of this act in Scripture is therefore called forth by a disobedience to hygienic law.

The habit helps to spread infectious disease. It also prepares the way for famine by removing from their proper place ingredients required for the nourishment of plant life in their most available form. It is often said that it will not pay a locality to utilize its sewage in the manner which I advocate, that to spend a sovereign in a way only likely to bring back ten shillings is economically wrong. This might be so if there were no other contingencies to be considered. But let me put before you the results of sanitation in my own town, Croydon. A death-rate of

26 per thousand and a rating equal to 6*s.* in the pound, more than 35 years ago, was followed by the capital expenditure of some 600,000*l.* in sanitary works for a population of 36,000 persons, gradually increasing in numbers as the expenditure went on. The death-rate has averaged, for the past 10 years, 14 per thousand, and the rating is at this moment 5*s.* 4*d.*, though, in addition to a high Metropolitan Police rate, a School Board, public baths, public libraries, and nine public parks for the recreation of the people have been established in the district. The expenditure on sanitary works gives a beneficial return to the locality as well as to the nation, and has added much wealth to the district in which the works have been carried out.

The people of Croydon have expended some 230,000*l.* in the purchase of land for the purpose of sewage utilization during the past 30 years. They were prohibited by law from fouling the Wandle river, and injunctions obtained against the local authority before the year 1860 have never been dissolved, yet the effluent from the sewage farm has been discharged into the Wandle, and the authority has been unmolested by law ever since they applied the sewage to the land in the manner which is termed broad irrigation, while the cost to the ratepayers (exclusive of the purchase of the land) has never exceeded a twopenny rate. What have we had for this rate? Improved health, the employment of a large number of hands at improved agricultural wages, exceeding by five times the number formerly employed on the same land, a large increase in the amount of meat and milk at the service of the people, and, so far, the nation ensured against the chance of evil from scarcity. Surely these results are far in excess of the burden imposed. It is, in my opinion, a national mistake to allow the continuance of waste in the face of such national advantages.

Let me now turn to the condition of the Thames. It receives the sewage of the metropolis, which is treated chemically at an immense cost to the London County Council. The Croydon local authority used a lime process when the sewage was first applied to the land, it being then supposed to be a necessity of the work. Some large sums were annually expended in this operation, and nuisance was actually produced by the sanitary authority in the places where the tanks existed. These were removed some 15 years ago, and the sewage has ever since been discharged directly upon the land, without any other process than a rough straining through wire guards. The expense of treatment in tanks by the lime process has been saved, and it has been clearly demonstrated by our experience that such treatment is entirely unnecessary. If fresh sewage is discharged immediately upon the land before putrefaction has commenced, no evil will result to the locality to which it is conveyed. If sewage is kept moving at a fairly rapid rate no opportunity for putrefactive action will be given, and the sewage may be conveyed 40 or 50 miles in either closed or open courses with safety, provided that the closed mains are kept filled with moving sewage.

Let me apply the principle of this form of utilization to the sewage of London. Take the population at about 4,000,000. The average agricultural value of the refuse of each individual may be roughly

estimated as equal to that of a sheep for the same purpose. This has been put at 5*s*. per head by competent authority. Assuming this to be a minimum value, the sewage of London is worth, in the abstract, a million a year, independently of the national advantages which would result from its utilization. Let us assume, for a moment, that these advantages would justify the nation in guaranteeing the interest of 3 per cent. on 20,000,000*l*. devoted to such a purpose. If that amount were judiciously expended in promoting the Canvey Island or Maplin Sands' scheme, together with the erection of pumping stations at favourable points on the present collecting sewage outfalls, with covered rising mains conveying the sewage to high lands beyond the populous districts around the metropolis, immense areas of barren, uncultivated land might be converted into farms, producing luxuriant crops, and large agricultural populations would be provided with the means of subsistence, while increased supplies of milk, meat, and vegetables, would be at the command of the people, and, so far, there would be diminished scarcity of supplies in the event of complications with foreign nations. This would help to bring about the effects which are expected to result from the principle of allotments, now so strenuously urged upon Parliament by the advocates of healthy employment for the people. The estuary of the Thames would be freed from a condition which is a standing disgrace to a civilized community, and which, if persevered in for another half century, will inevitably damage the navigation of the river, and consequently the trade of the port of London.

Seven or eight years ago I acted as one of a committee for the erection of a third lunatic asylum for the county of Surrey. We arranged for the utilization of the sewage of 1,200 inmates by broad irrigation. The area irrigated is absolutely within a stone's throw and in front of its principal entrance. I append a letter received from the medical superintendent as to the result. I may add that the asylum has recently passed out of the care of the Surrey magistrates into the hands of the London County Council.

London County Asylum,
Cane Hill, Purley, R.S.O.,
April 4, 1891.

DEAR DR. CARPENTER,

. . . .

No report on the result of our sewage utilization has been recently published. The sewage, as you are aware, is disposed of here on the land by gravitation. The process is simple in the extreme, one man managing the whole affair.

1. The health of the population of the asylum is unaffected in any way. Not the slightest discomfort or nuisance arises from the land irrigated, and this although it immediately adjoins the Brighton Road.

2. Italian rye grass is grown in large quantity, and is consumed as summer feed by the cows and horses. The portion irrigated is cut for two years, then ploughed and cropped for the two following with roots (mangold) and oats.

3. Financially, there is considerable profit, as the stock would require a much larger area of land if fed by grazing, or else a large outlay for some substitute for the rye grass.

Amount of land irrigated, nine acres. Asylum population, 1,250. No effluent.

Believe me,
Yours very truly,
JAMES MOODY.

About 20 years ago, the burgomaster of Dantzig, with a deputation from the governing body of that city, visited Croydon, and inspected our sewage farm. As a consequence of that inspection and of other information afforded to them, a sewage farm has been established at Dantzig, I now publish a letter from the manager of the farm.

Danzig Sewage Farm,
September 1, 1890.

DEAR SIR,

I HAVE been following, with great interest, the accounts in the "Times" of the meetings of the Sanitary Congress, and I cannot help writing you to confirm, from my experience, the views which you have expressed, viz., "the establishment of a number of sewage farms would "be better. It would be more desirable, instead of wasting the sewage, "to distribute it over an area where it could fructify. With people so "much in need of meat and milk as Londoners were, it was criminal to "destroy such a valuable means of production of those commodities." I have no doubt whatever the County Council will soon find itself compelled to do something besides polluting the seaside as well as the Thames, and no better beginning could be made than by carrying out the Maplin Sands or even the Canvey Island scheme. I am confident the result would be satisfactory, and that other sites would soon be offered or found. It is to me quite incomprehensible that the Council has taken no opportunity of viewing the Berlin sewage farms, which, despite the enormous outlay, are a most complete success. If the 1,720,000 inhabitants and ratepayers are *quite* agreed as to this, surely it is worth while looking at. Our farm here in Danzig has been visited this year by a great number of authorities from all parts of the world, exciting wonder as well as interest, for year by year the results are more satisfactory, financially as well as agriculturally. Only last week we entertained a large party of visitors from Austria, who were very much astonished to find whole plantations of Edelweiss, and to drink the capital red currant wine which is so much esteemed here, produced on the sand of the sea shore by the utilization of the Danzig sewage. Asparagus continues to be one of the best paying products, and commands a much higher price than that produced on the inland farms.

Yours respectfully and faithfully,
ALEX. AIRD.

Alf. Carpenter, Esq., M.D.

In addition, I may add the testimony given by Dr. C. E. Saunders, Medical Superintendent of the Sussex County Lunatic Asylum. When the congress of the Sanitary Institute was sitting at Brighton last year he invited the members to view the irrigated land at Hayward's Heath. He stated that the food grown upon the farm had all been consumed, directly or indirectly, within the asylum, and he pointed to the com-

paratively low death-rate at the asylum, and the absence of all zymotic maladies as a clear proof that the food used was free from all disadvantages.

I propose to deal with the objections that have been made on sanitary grounds to sewage farming in a second paper.

The Power of Soil and Vegetation combined to destroy Disease Germs, and so to prevent the Possibility of the Spread of Enthetic Disease in consequence of Sewage Farming.

BY

ALFRED CARPENTER, M.D.

At the meeting of the International Medical Congress in London in 1881, I had the privilege of introducing to the notice of the members the subject of sewage utilization by means of irrigation. I submitted nine propositions, and the evidence upon which those propositions were based, viz., the practical experience of 21 years' personal observation upon the Croydon sewage farms. A further experience of 10 years gained by closely watching the same farms (the areas being increased) has fully confirmed every word put before the great assembly of 1881. No essential part of that evidence has been successfully assailed, and every word might be repeated here if it could be done without loss of time. I will renew the propositions, so far as they bear on the power of soils to destroy the germs which in other positions are capable of spreading infectious disease.

Proposition 1.—That the judicious application of sewage in close proximity to dwelling-houses does not depreciate the health of the inhabitants. A continuation of the table then given of the vital statistics of the parish of Beddington and of the hamlet of Wallington will afford proof of this contention.

BEDDINGTON.

—	Population.	Rateable Value.	Births.	Deaths under 1 year.	Deaths over 60.	Total Deaths.	Birth rate.	Zymotic Disease.	Death rate.
		£							
1882 - -	2,485	17,689	64	6	3	18	25·7	None.	7·2
1883 - -	2,531	18,532	76	10	9	31	30·	None.	12·2
1884 - -	—	19,120	76	8	8	27	—	3	—
1885 - -	—	19,258	62	5	4	26	—	2	—
1886 - -	—	19,684	78	9	8	31	—	6	—
1887 - -	2,950	20,325	72	8	8	25	24·4	2	8·4
1888 - -	3,000	20,260	72	4	5	23	24·	1	7·6
1889 - -	3,050	20,156	58	3	3	12	19·	None.	3·9
1890 - -	3,250	20,216	61	6	6	16	18·7	2	4·9
1891 - -	—	20,203	—	—	—	—	—	—	—

WALLINGTON.

—	Population.	Rateable Value.	Births.	Deaths under 1 year.	Deaths over 60.	Total Deaths.	Birth rate.	Zymotic Disease.	Death rate.
		£							
1882 - -	3,007	21,912	89	12	10	43	29·5	None.	14·3
1883 - -	3,053	22,578	75	5	8	31	24·5	None.	0·1
1884 - -	—	23,217	92	10	8	33	—	2	4
1885 - -	—	23,888	85	9	19	48	—	2	—
1886 - -	—	25,870	110	8	14	33	—	1	—
1887 - -	4,900	26,172	101	9	7	35	20·5	4	7·1
1888 - -	5,500	26,126	72	10	19	41	13·	4	7·4
1889 - -	5,600	26,176	98	8	13	37	17·5	3	6·6
1890 - -	5,900	26,707	100	10	11	35	16·9	6	5·9
1891 - -	—	26,761	—	—	—	—	—	—	—

It will be observed from this table that the population has increased in a very rapid ratio, which is the more manifest when compared with that of 1861. The census of that year gave a population for the combined districts of 1,557, and a rateable value of 11,700*l*. Notwithstanding the existence of the sewage farm within the distance of less than a mile from the extreme limits of the district, there has been a rapid increase in both population and rateable value. The high birth rate has naturally raised the death rate, quite independently of outside influences, and the zymotic rate includes diseases such as whooping-cough, which cannot be laid to the charge of the farm.

Proposition 2.—That the judicious application of sewage to land will satisfactorily cleanse the effluent water, and fit it for discharge into any ordinary rivulet or water course. Recent analyses of the Beddington effluent, show that after 31 years continuous application of sewage to the same land, there is a persistent power in that land to deal with the applied sewage as satisfactorily as was the case when it was examined by the River Pollution Commissioners in 1867, as reported to Parliament. It may be that the effluent has not been at all times equal to these analyses. Errors of management, absence of manager, great rainfall, cleansing of carriers after haymaking or grass cutting, and the flushing which has to take place after such cleansing, tend for the moment to make the effluent chemically less satisfactory; but in no case has this been more than an accident, which can be, and has been, easily remedied. I need not labour at this proposition. Its truth has been abundantly demonstrated at other places besides Croydon, though not over so long a period of time, and chemical analyses of a highly satisfactory kind have been published in the sanitary journals.

Proposition 3.—That vegetables from fields continuously irrigated by sewage are satisfactory food for man and beast; that animals fed mainly on sewage produce are as healthy as animals fed on ordinary agricultural produce. I prove this by the emphatic statement that no evil effects have been shown to have followed from the consumption of the food which has been grown upon the 600 acres of land irrigated by

the Croydon sewage, or on the 1,200 acres irrigated by the Birmingham Corporation. The immense quantities of food in the way of meat and milk resulting from these large areas must have shown evidence of their unsoundness, if any had really existed. If, in addition to this, I take the evidence afforded by medical superintendents of lunatic asylums, such as that given in September by Dr. C. E. Saunders at Haywards Heath, and Dr. Moody at Cane Hill, it will not be necessary to write more to refute the imaginary notions of those who assume that sewage-grown produce must be unwholesome.

Proposition 4.—That excretions of those suffering from infectious and epidemic disease, when distributed upon land, as in broad irrigation, are immediately rendered innocuous. If rightly dealt with they cannot spread such diseases to those employed on the farm, or injure those who consume the produce, or set up similar disease in those living on the confines of the farm. No evidence has been adduced to contradict this proposition. I append extracts from the reports of the medical officer of health, who, acting for the rural sanitary authority, was not under the jurisdiction of the Croydon authority, and therefore gave an independent opinion.

Mr. Cressy reported (Lady Day, 1883): "I have to report for the " year 1882, an immunity from fever of every kind. The area reported " upon includes an asylum of 170 girls from 8 to 16 years of age, which " has a remarkable freedom from zymotic disease." This paragraph refers to the Beddington Female Orphan Asylum, a building containing nearly 200 occupants, and placed at the south-west corner of the farm, separated by a small brook from fields frequently under irrigation; and a north-east wind carries with it any miasma produced by more than half a mile of irrigated land.

In 1883 there was no outbreak reported except one, which the medical officer considered to have been caused by polluted water. There were two cases of enteric fever resulting in one death.

In 1885, six cases of diphtheria were reported as arising in South Beddington, in houses at a high level on the chalk (a point the most distant in the parish from the farm) traced to local sanitary defects.

As to 1886, Mr. Cressy reports: "There has been no outbreak of " zymotic disease. A case of diphtheria did arise which was imported, " but there was no extension." Mr. Cressy, taking a survey in concluding his report says: "The district has been very free from infectious disease."

In 1887, two cases of typhoid, one being fatal, were reported, and referred to dirty hand-flushed w.c.'s. "The record, as far as infectious disease is concerned," says, Mr. Cressy, "speaks for itself."

In 1888, he says: "I find the health of my district even better than last year."

These reports corroborate the view put forth in 1881 to the fullest extent. It is true that a new medical officer of health has been recently appointed, who signalised his first report by a suggestion that as he had been unable to trace an outbreak of scarlatina in the Beddington Female Orphan Asylum, it might be produced by emanations from the Croydon sewage farm. This opinion is not supported by evidence worthy of

credence:—(1.) If it were true, scarlatina must have continuously affected the inmates of the school, and but few, if any, of the children sent there would have escaped the disease. The late Mr. Cressy's reports directly contradict this theory. (2.) There are living on the farm several families of children; most of them have not been affected by scarlatina. (3.) Considerable numbers of children at Hackbridge on the west, and at Waddon on the east, have never suffered from scarlatina; and the South Norwood district of Croydon, which is close to the South Norwood farm, has been singularly free from this disease as compared with other districts, and even with other parts of the borough of Croydon where scarlatina does not exist to anything like the extent found where there are no sewage farms. This clearly shows that the germs which promote the spread of scarlatina are not multiplied in areas devoted to broad irrigation, and it may be fairly assumed that the allied zymotic disorders are not capable of propagation from such areas, otherwise those diseases would be found to be more prevalent among the neighbouring residents than elsewhere. This is certainly not the case at Beddington or Norwood, or in the neighbourhood of any other sewage farm with which I am acquainted. Yet cases of scarlatina do occur in the borough of Croydon, in sufficient numbers for me to say that in no single month in any year have the excreta of scarlatina patients failed to reach the farm at Beddington.

Surely this evidence must be conclusive. I contend that the excreta of infectious patients are not capable of spreading infectious disease unless they have undergone a zymosis, which cannot take place if the excreta are cooled at once, aërated as they are on the surface of the soil, and brought into contact with the humus of the earth and the rootlets of the growing crops. An experience of 31 years has not produced any evidence to contradict this proposition. Sewage must be kept near to the surface of the soil so as to have the advantage of sunlight, air, and vegetable life. If sewage percolates deep into the soil out of reach of air and light, the ova of disease germs may be preserved ready for use upon some other opportunity, and possibly carried away in the effluent water. It is requisite, therefore, that ova be destroyed as well as the germs themselves. This destruction is best effected by vegetable life, and the means whereby this comes about are most numerous on the surface of the soil itself.

In close proximity to the north-western border of the farm is the populous village of Mitcham. Hear what Mr. Marshall, the medical officer of health, reported to the rural sanitary authority in the spring of this year. "Considering the amount of sickness at the beginning of the year as due to the prevalence of the influenza," and at the end of the year to the "severity of the weather, I think the mortality very moderate, "as was also the amount throughout the year of zymotic disease. "There has been in the district scarlet fever of a mild type, and only "one death is recorded."

Birth rate for year ending 31st March 1891			-	29·51
Death rate	,,	,,	,, - -	11·93

The population of Mitcham is estimated at about 12,500.

Proposition 5.—When examining into this subject some years ago, I carried out a series of observations upon the power of rye grass to deal with the organisms found in sewage. A cubic yard of soil from Beddington was placed in a container and sown with rye grass. The seeds were treated every day with sewage dressings, and the application continued until effluent appeared at the provided outlet. The applied sewage was of the ordinary character; but occasionally urine, swarming with bacteria, was added. Microscopic examination of the effluent failed to discover any of these organisms in the liquid, even after it had been kept for three days. The best time to see the reason of this exemption is about the time at which the plant comes into flower. If the surface of the field is then closely examined, it will be seen to be covered by a felt like mass of minute radicles extending from the plant at the point at which it is attached to the soil. As the sewage is applied, the rootlets seem to be endowed with life, to become mobile; the bacteria adhere to them as they pass with the sewage through the living filter, and if these rootlets are examined through a magnifying glass, the germs are seen in an hour or two to disappear from view, as if digested by the plant itself. Hence I have presumed to apply to rye grass the term carnivorous.

It is by this natural process that the ova of disease germs are removed from the sewage, and the effluent satisfactorily cleansed. A similar result occurs when vegetable life is not active. The ulmic salts in the upper part of the soil have an attraction for living organisms similar to that existing in living vegetable root fibres. This humus is only to be found on the surface of the field, and this is the reason why sewage must not be allowed to filter deep into the soil. Intermittent downward filtration is not safe in its results, because the cleansing power of the humus may be overtaken, and disease germs escape with the effluent.

A microscopic examination of the soil from Beddington, showed myriads of living organisms within the first three inches of the surface. At a depth of one foot there were found not to be more than a tenth part of those nearer the surface. At two feet deep they were much less numerous; at the depth of a yard they were sometimes absent altogether, though the surface had been irrigated, more or less, during the whole of the year preceding that in which these experiments were carried out. The bacteria found in the soil evidently feed upon the organic matter contained in the sewage, and change it into elements fitted for plant use. It is thus that nature protects us from the natural consequences of animal existence. We have only to see that the laws of the universe are obeyed, and we then escape from the incidence of those diseases which disobedience entails. At the same time we grow increasing quantities of food for those who produce the sewage.

The proposition, therefore, is—Sewage when kept in motion and quickly brought into contact with soil and vegetable life is changed in a direction contrary to that which is necessary for the propagation of disease germs. It has been asserted that parasitic diseases are spread by sewage farms. I persistently searched for evidence of this before the year 1875, and have continued my observations since. I have not

met with cases of *tænia solium*, or tape-worm, in Croydon; there is no evidence of its existence in the case books of the medical officers reporting to the destitution authority (Board of Guardians). If cases had existed, some notice of them must have been found. I placed a mass of evidence on this point in the hands of the late Dr. Cobbold, and invited him to come down and examine for himself a large herd of oxen about to be slaughtered, which had been bred and grown on the Croydon farm. Dr. Cobbold at that time was in bad health and could not come; but, in a letter to me, he withdrew the charges he had made suggesting possible evils attendant on the establishment of sewage farms.

A microscopic examination of the flesh of those animals did not show a particle of evidence in support of the allegations.

To conclude, I have put before you a survey of every point bearing on the hygiene of sewage farming, and I claim to have proved that the utilization of sewage in the manner indicated is a national advantage.

DISCUSSION.

Sir Henry Roscoe hoped the discussion would take a purely scientific direction. He regretted the absence of Dr. Dupré on account of ill-health, as he had undertaken to bring before the Section the present mode of treatment of the London sewage. He, the President, had not been an advocate of the mode of treatment adopted by the late Metropolitan Board of Works and continued by the London County Council, and he therefore the more regretted that the subject could not be fully discussed. The President called attention to what he considered a most admirable report on sewage, which had just reached him, by the State Board of Health of Massachusetts. From the most elaborate series of experiments, both chemical and bacteriological, made upon the system of intermittent filtration, a most important fact was brought out which had hitherto been overlooked, namely, that in the process of the filtration of sewage through sand the action is not merely a straining out of the suspended particles, nor is it a merely chemical one; but by far the most important action is a purely biological one, inasmuch as each grain of sand appears to become the nucleus of a peculiar condition of the nitrifying organism, the activity of which brings about the nitrification and purification of the sewage applied to the filter. Air is absolutely necessary for this process of purification, and hence the importance of the filtration being intermittent. He believed the Section would be interested to hear the results of this important investigation, and that the Section would congratulate this American Congress on the remarkable work which they had carried out.

Mr. H. Alfred Röchling, C.E., said: Difficulties with the Leicester sewage, where he had been connected with the public works of the town, and where since 1855 almost every known chemical process had been tried and had signally failed, had forced the subject of sewage farming upon his notice; and the Berlin farms being the largest in existence, he had very carefully inquired into their working since their establishment. The Berlin Municipal Authorities, and especially Herr Marggraff, the Commissioner of the Farming Committee of the City Council, had generously placed a large amount of information concerning the farms in his hands by supplying him with plans and the yearly

reports, from which he had abstracted the following information: The total area of the irrigation farms has now reached 18,796 acres, but of this total only 7,942 acres are sewaged at present; the rest is being prepared as necessity occurs, the drainage of the city being extended every year. The land is bought when a suitable opportunity offers, and is farmed in the ordinary way until required for the disposal of sewage. The 7,942 acres sewaged at present are all in the four original sewage farms, which have an area of 11,016 acres; nearly all the sewage-treated land is under-drained. The following details refer solely to the four original farms: In Berlin all the liquid refuse from the houses goes into the sewers and is, together with some portion of the storm-water, lifted onto the farms by powerful machinery. The two southern farms are about 12 miles, and the two northern farms only about six miles, from the heart of the town. During the year 1889–90 (from 1st April 1889 to 31st March 1890, the official year) the sewage occupied about 10 to 12 hours in traversing the distance from the pumping station to the southern farms. The subsoil on the farms is chiefly sand, passing in places to sandy loam or loamy sand. There are three different modes of applying the sewage to the land, viz., in sloping grass plots (broad irrigation); in nearly level beds (filtration); and in perfectly level tanks (filtration). In broad irrigation the sewage enters the plot at the top, fills a small trench, and flows in a thin layer down hill. In filtration the land is divided into ridges about one yard wide, separated from each other by a trench, the ridges being generally planted with root crops, and the sewage is allowed to fill the trench only, in which it has to stand, getting sideways at the root of the crops but not coming into direct contact with the plant, and filtering away into the subsoil. In winter, when the ground is frozen to such a depth as to make irrigation impossible, the sewage is turned into large earthen tanks in which it stands till it has all disappeared in the subsoil. This mode of application is limited only to times of severe frost, and the area on which it is practised is only about one-twentieth of that specially prepared for sewage treatment; as might be expected, it does not purify the sewage to such an extent as either of the other modes. The expenses in connexion with the purchase and laying out were as follows (up to 31st March 1890):—

Purchase, 40*l.* 9*s.* 9*d.* per acre; distribution of sewage, 13*l.* 9*s.* 10*d.* per acre; laying out, 8*l.* 12*s.* 2*d.* per acre; draining land, 6*l.* 1*s.* per acre; sundry expenses, 4*l.* 9*s.* 6*d.* per acre: Total 73*l.* 2*s.* 3*d.* per acre.

The total quantity of sewage disposed of on the farms since their establishment has been 350,673,798 tons; and though they have dealt with this large amount, the land does its work to-day as well as ever it did before. The farms were practically not complete till 1885, and in the first year of complete farming (year ending 31st March 1886) a profit, in management only, of 1,509*l.* was realised, whilst in the year ending March 1889, a profit of 11,511*l.* was realised. If annual payments for capital expenditure are taken into consideration, all the profit of course disappears and is, indeed, changed into a loss; but even then it took only a rate of from 0·82 to 0·97 of a penny in the £ of the rateable value of property connected with the sewers to make up for the deficiency in the years 1885–90. The total expenditure for sewerage and sewage disposal works has now reached the sum of 4,080,440*l.* Professor D. Salkowski, of the Berlin University, has carried on a systematic investigation of the effluent waters from the farms, and has made altogether 296 analyses (up to 31st March 1890); from these it appears

that grass plots (broad irrigation) have abstracted 93·89 per cent. of organic pollution—as expressed in parts of permanganate of potash—and 98·15 per cent. of organic ammonia; beds (filtration) have abstracted 92·56 per cent. of organic pollution—as expressed in parts of permanganate of potash—and 97·72 per cent. of organic ammonia; tanks have only abstracted 82·60 per cent. of organic pollution. In connexion with the sewage farms the authorities have established a perfect system of recording not only all deaths but also all cases of sickness. Between 1885 and 1889 the average population per annum on the farms was 968 men, 825 women, and 327 children, or a total of 1,580 (61 per cent. men, 18 per cent. women, and 21 per cent. children); but of the total grown-up male population of 968, 850 are "correctionists" (street loafers, &c.) impoverished in health. The death-rates per 1,000 for all classes were 11·24 in 1885, 9·22 in 1886, 14·83 in 1887, 6·79 in 1888, and 4·81 in 1889. For the seven principal zymotics the death-rates per 1,000 were 4·32 in 1885, 3·69 in 1886, 4·15 in 1887, 1·13 in 1888, and nothing at all in 1889; or, if the cases are enumerated, there were in this period (1885 to 1889) seven deaths from scarlet fever, nine from diphtheria, one from typhoid, and three from diarrhœa, all, without exception, among children under 15 years of age. In 1889 there was a somewhat severe epidemic of typhoid fever in the city of Berlin, but not one case of typhoid fever was reported on the farm.

Dr. J. H. Gilbert said that, dismissing the subject of the methods of chemical treatment of sewage as a means of purification or of utilisation, as of comparatively temporary or limited utility, he would confine his attention to the application of sewage to the land. The two questions, of purification and of utilisation, must to a certain extent be viewed separately. If the position of a town were such that sufficient land for utilisation could not be obtained or reached without prohibitive expense, in most cases enough might be available for purification to the extent necessary to allow of the effluent passing into a river. Sometimes more or less utilisation may at the same time be combined. When, however, utilisation is a prominent object much more land is essential. But if, as should be the case, the application is mainly restricted to the growth of succulent crops, the area necessary would be much less than were the arrangements made with the object of including the growth of ripened crops, which require, and will bear, much less water. At the same time, assuming the scheme to be specially adapted for the growth of succulent crops, and mainly for the production of milk and meat, more or less land might sometimes be devoted within the area to the growth of grain or other ripened crops by limited irrigation, or by the use of the manure of the animals fed, if this be not made to contribute to the sewage. So far as we at present know, the purification necessary to allow of the effluent being discharged into a river is reached when practically the whole of the soluble organic nitrogen is oxidized into nitric acid; and in our climate it would only be for short periods of the winter that this result would not be sufficiently attained under proper management. A question arises, however, whether—although all the nitrogenous compounds were oxidized—all injurious organisms would be removed, and this is a point requiring further investigation. But obviously it would be an advantage if the organisms effecting the several stages of the nitrification process were not removed, but passed into the river. There can be no doubt that, although purification is of first importance, utilisation for succulent crops, which would take up the manurial matters more

or less almost the year round, would according to the degree in which local conditions, cost of distribution, &c., permitted, greatly increase the production of the important foods, milk and meat, and more or less that of other products. Yet, it was hopeless to suppose, that by the return of the constituents of sewage to the land, our country would be able to produce all the food required by the population. Cost of distribution must limit the area irrigated and the crops grown, and there must be waste of manurial matters, more or less, according to the local circumstances. But all the produce that can be obtained is so much to set off against the essential cost of purification; though it would probably be only under very exceptional local conditions that a direct profit on the outlay for removal, distribution, and management, could be expected. Application of sewage to the land, however, was undoubtedly the best known means of purification, and, notwithstanding the necessary limitations to its general applicability as manure, so far as present experience goes, it also promised the best result so far as utilization was concerned

Colonel Jones, V.C., agreed entirely with the remarks of the President on Dr. Thresh's paper, and stated his view of the practical question, "Will a sewage farm pay?" As regards the London question, he referred to the Canvey Island scheme, and challenged Dr. Dupré and his co-fellows of the Royal Society to reply to his article in the "Fortnightly Review" for July 1886, stating that the present state of the Thames, as evidenced by the medical officer of the port of London, and a petition from Woolwich recently presented to the London County Council, was now worse than on any previous occasion.

Mr. G. H. Bremner advocated the application of a process of aëration to sewage.

Dr. C. R. Drysdale expressed his gratitude to the former speakers for their remarks, and especially to Dr. Carpenter, who might be called the father of sewage-farming in England. It was from England that France and Germany had first learnt the value of sewage-farming, but those countries had now, so far as the capitals were concerned, left us far behind in the matter. Paris and Berlin had large irrigation farms in very successful operation, and the results obtained there made it still more distressing that London should be so supine in this matter, and go on pouring 180,000,000 gallons of sewage daily into the river instead of employing that fertilising process in the raising of meat and milk for the inhabitants of London.

Mr. T. J. Perry (Camberwell) advocated the adoption of the radial method of distributing sewage as opposed to centralisation. London should be divided into 12 districts, each of which would produce about 17,000 gallons daily, storm-water being dealt with separately. Although in favour of the system of irrigation where applicable, he would not himself care to live near a sewage-farm.

Mr. W. C. Sillar defended the A.B.C. process for removing sewage, now in operation at Kingston-on-Thames, regarding it as a better and more practical system than irrigation, and pointed out the great demand for the manure thus obtained. He denied the statement that ammonia and phosphates were added to the manure to increase its value.

Dr. C. E. Saunders insisted on the absence of nuisance or other dangers to health in the proximity of a sewage farm when the sewage is properly dealt with by broad irrigation. He objected to the introduction

of a commercial element into the discussion, as the scientific aspect of the case should not be mingled with the commercial.

Dr. Alfred Carpenter stated that the crude matters are first removed from the Croydon sewage, and the latter then passed directly on to the land. With regard to the statement that people would not care to live near a sewage farm, he pointed out that there were many villas around the Beddington farm.

Dr. E. Haughton was prepared to provisionally support the use of sewage by spreading it over sewage farms, but did not consider all localities suitable for the purpose, and hoped the day would come when the dry method would be perfected, and the so-called sewage system would be superseded by the no-sewage system.

Alderman Boulton (Corporation of Burslem) stated that the irrigation system had been adopted at Burslem with great success, but deprecated the fact that the land obtainable for this purpose was always sold at much higher than the market price.

Mr. Cripps (Tottenham) pointed out that the system mentioned in Dr. Thresh's paper as being in use at Tottenham had now been given up, and that Tottenham had paid a fine of 30,000*l.* to join the Metropolitan sewage system.

Thursday, 13th August, 1891.

The President, Sir H. Roscoe, in the Chair.

Kritische und experimentelle Studien über die hygienische Bedeutung des Kupfers.

VON

Professor Dr. K. B. Lehmann, Vorstand des hygienischen Instituts, Würzburg.

Seit der Mitte des vorigen Jahrhunderts beschäftigt die Kupferfrage die wissenschaftliche Welt. Bis zu den fünfziger Jahren dieses Jahrhunderts war das Dogma von der hohen Gefährlichkeit des Kupfers trotz vereinzelter Widersprüche unbefangener Beobachter (z. B. Ellert) allgemein acceptirt, dann folgte eine gewaltige Reaction, die in dem Satze gipfelte: "*Kupfer ist kein Gift.*" Namentlich Erfahrungen practischer Aerzte über die Ungefährlichkeit der Anwendung selbst hoher Kupferdosen bei der Behandlung von Croup waren unvereinbar mit der Lehre von der hohen Giftigkeit.

Die sorgfältigen Arbeiten der letzten Jahrzehnte, unter denen namentlich die von Toussaint, Galippe und Du Moulin genannt sein

mögen, haben weitere Klärung gebracht. A. Gautier's verdienstvolle Schrift "Le Cuivre et le Plomb" hat in weiteren Kreisen maassvolle Anschauungen über die wahre toxicologische Bedeutung des Kupfers zu verbreiten gesucht.

Derselbe Autor hatte auch mit Bouchardat auf dem hygienischen internationalen Congress in Paris 1878 die Reverdissagefrage zu behandeln, die er im Sinne eines Compromisses zu lösen vorschlug: Es sollten bis 18 mg. Kupfer (die gerade für Erbsen hinreichende Menge) pro Kilo Gemüse zugelassen werden. Da Bohnen mehr Kupfer zu ihrer Grünfärbung bedürfen, als Erbsen, so sind jetzt, meines Wissens, 40 mg. Kupfer pro Kilo Gemüse in Frankreich zugelassen.

Aber trotz dieser Aufklärungen findet man noch in den weitesten Kreisen Unklarheit in der Kupferfrage. Wie weit die Ansichten unter hervorragenden Aerzten und Toxicologen noch auseinander gehen, bewies aufs Klarste die fast endlose Debatte der belgischen Academie 1884, die über die Frage des Ministers entbrannte, ob ein Kupferzusatz zu Nahrungsmitteln als gesundheitsschädlich zu betrachten sei.

Du Moulin vertrat, von einigen Collegen unterstützt, die These: "Kupfer ist kein Gift" bis in alle Consequenzen, wurde aber von der Mehrheit überstimmt. Doch gingen die Ansichten seiner Gegner weit auseinander, es fanden sich alle denkbaren Abstufungen der Beurteilung des Kupfers von der ächten Cuprophobie bis zur kritischen Würdigung der wirklich nachgewiesenen Schädlichkeiten neben einander vertreten. Der Beschluss lautete: "Es sei dem Minister zu empfehlen, jede " Anwendung von Kupfersalzen zu Speisezwecken zu verbieten, da sie " schädlich seien."*

Die Darstellung aller Autoren leidet unter dem in der Litteratur stets hervortretenden Widerspruche:

So viele therapeutische und experimentelle Erfahrungen scheinen eine relative Unschädlichkeit des Kupfers bewiesen zu haben, daneben enthält bis in die allerneueste Zeit die Litteratur fortwährend vereinzelte Berichte über schwerste akute Vergiftungen durch relativ geringfügige Kupferdosen. Die Unsicherheit der Verfasser der Lehrbücher tritt auch in den gerichtsärztlichen Gutachten immer wieder zu Tage. Auch die Frage der chronischen Kupfervergiftung wird von den meisten Autoren ohne rechte Ueberzeugung verhandelt.

Bei diesem Stande der Frage schien es mir erspriesslich, mit einigen Schülern noch einmal ein vorurteilfreies, gründliches experimentelles und litterarisches Studium der Kupferfrage vorzunehmen und ich hoffe bei der Section Interesse für eine kurze Darlegung der wichtigsten Resultate zu finden. Auf die Wiedergabe von Einzelheiten und eingehender Litteraturkritik und Litteraturcitirung muss ich natürlich hier bei der Knappheit der zugemessenen Zeit verzichten.

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* Eine Substanz nenne ich im Folgenden *gesundheitsschädlich,* wenn sie in den Dosen, in denen sie in den Körper gelangen kann, eine unverkennbare, wenn auch leichte und vorübergehende Störung der Gesundheit bedingt, *giftig,* wenn sie schwere Störungen oder den Tod verursacht. Man hat vielfach den Forschern, welche die Giftigkeit der Kupfersalze leugneten, die Ansicht zugeschrieben, auch ihre Schädlichkeit zu leugnen; so weit ist aber kaum einer gegangen.

I.

Da hier nur von der ökonomischen Bedeutung des Kupfers gesprochen werden soll, so ist vor Allem anzugeben, welche Kupfermengen durch den Haushalt überhaupt in den Körper gelangen können.

Wir brauchen bei dieser Ueberlegung den natürlichen nicht unbedeutenden Kupfergehalt zahlreicher Vegetabilien nicht mit in Rechnung zu ziehen, da derselbe hygienisch offenbar ganz bedeutungslos ist. Es interessirt uns nur der Ueberschuss über diese normale Menge, wie er auf zwei Wegen in die Nahrung kommen kann.

1. Durch absichtlichen Zusatz von Kupfersalzen:

a. zu Gemüsen zwecks Grünfärbung (Reverdissage);

b. zu Mehl, um seine Backfähigkeit zu erhöhen, das Aussehen des daraus gebackenen Brotes zu verbessern und seinen Wassergehalt zu vermehren.

2. Durch Nachlässigkeit:

a. unpassende Verwendung *reiner* Kupfer- oder Messinggefässe bei der Speisebereitung, d. h. Stehenlassen saurer oder fetter Speisen in Metallgefässen nach dem Kochen;

b. Verwendung ungereinigt stehen gelassener, grünspahnbeschmutzter Kupfergeräthe.

Es handelt sich um exacte Angaben, welche Mengen von Kupfer auf diesem Wege in den Körper gelangen können:

1. Durch absichtlichen Zusatz:

a. In Gemüseconserven sind gefunden in 1 Kilo:

(1) von Riche und Magnier de la Source:

in Erbsen - - -	16 Milligramm Kupfer
in Gurken - - -	18 „ „
in Bohnen - - -	35–45 „ „

(2) von Gautier:

im Durchschnitt	etwa 60
im Maximum	125
im Minimum	16

In Deutschland fand soeben Mayrhofer etwa 25–35 mg. Kupfer im Durchschnitt in vegetabilischen Conserven.

Die höchsten Werte, die bisher gefunden wurden, sind:

184	Pariser Laboratorium, Erbsen.
180 u. 270	Chatin u. Personne, Erbsen.
200	Cronquist, Stockholm.

Wo Angaben vorhanden sind, heisst es meist, dass der Geschmacksinn diese Kupfermengen nicht entdeckte.

Um zu bestimmen, welche Kupfermengen sich in Gemüse hineinbringen lassen, ohne dass sich der Kupfergehalt dem Geschmacksinn verräth, habe ich absichtlich Gemüse mit Kupfer behandelt und ihren Gehalt analytisch festgestellt.

Erbsen mit 186 mg. im Kilo schmeckten noch gar nicht nach Kupfer.

„ 244 „ haben keinen Kupfergeschmack.

II.

Fragen wir nun, gestützt auf die ermittelten Zahlen, welche Kupfermengen können im ungünstigsten Falle durch eine Mahlzeit in den Körper gelangen, ohne dass es den Sinnen zu sehr auffällt? Die grüne oder blaugrüne Farbe, vor allem aber der adstringirende Kupfergeschmack, werden ja vor allzugrossen Mengen warnen. Nehmen wir an, dass die Mahlzeit bei Licht oder schlechter Beleuchtung verzehrt werde, so dass die blaue Farbe der Speisen weniger bemerkt wird, so können wir nur durch den Geschmacksinn aufmerksam werden.

Im schlimmsten Fall könnte so etwa bei einem wenig empfindlichen Gaumen in einer starken Mahlzeit in den Körper gelangen:

In 300 ccm. Suppe - - -	-	20 mg.
„ 1 Liter Wein, der in Kupfer stand	-	50 „
„ 50 ccm. Essig, „ „ -	-	10 „
„ 50 g. Fett, das zum Braten diente	-	5 „
„ 200 g. stärkst gekupferten Erbsen	-	50 „
„ 500 g. maximal kupferhaltigen Brotes	-	60 „

Also im Maximum 195 mg. Doch wird natürlich ein solcher Fall nie vorkommen.

Das leuchtet aber sofort ein, dass viel leichter in einer aus kupferhaltigem Brot und Conserven bestehenden Mahlzeit hohe Kupferdosen in den Körper gelangen, als durch Suppe, Ragout u. drgl., selbst wenn sie in grünspahnbedeckten Kupfergeschirren hergestellt werden, wenn nur keine stark sauren Gemüse in Kupfer gekocht und erkaltet sind.

Wenn wir die Conserven und das Brot ausschliessen, wird überhaupt selten mehr als 30–50 mg., kaum jemals 100 mg. Kupfer bei einer Mahlzeit in den Körper gelangen können, in Conserven und Brot dagegen ziemlich leicht 100, ja bis 200 mg.

III.

Auf die Frage, von welcher Menge ab reine Kupferpräparate bei einmaligem Einnehmen wirken, antwortet die Pharmacologie, dass Dosen von 10–30 mg. Kupfer in hinreichender Verdünnung meist wirkungslos sind, dass etwa 50–100 mg. Kupfer Ueblichkeit, Brechreiz und in der Regel Brechen erzeugen.

Auch von grösseren Dosen bis etwa 200 mg. (d. h. etwa 0·8 g. Kupfersulfat), auf einmal genommen, findet sich nirgends eine andere beglaubigte Wirkung als Erbrechen angeführt, höchstens sind noch kolikartige Leibschmerzen und schmerzhafte Diarrhoen erwähnt.*

Zu therapeutischen Zwecken fanden oft sehr grosse Dosen Verwendung. Kinder nahmen z. B. bei Du Moulin in 5–6 Tagen $1\frac{1}{2}$–$2\frac{1}{2}$ g.

* Mischt man Hunden oder Katzen, die vorher nie Kupfer erhielten, unter die Nahrung auf einmal eine concentrirte Lösung von 1 g. Kupfersulfat = 250 mg. Kupfer, was nicht immer leicht eingenommen wird, so brechen auch diese Thiere blos und zeigen keine weiteren Symptome. Tötet man sie, so sind höchstens ganz minimale Anätzungen an der Magenschleimhaut (Röthungen und Epithelabstossungen) zu sehen. Und doch entspräche diese Dosis (50–100 mg. Kupfer pro Kilo) beim Menschen einer ganz gewaltigen Gabe.

Kupfersulfat, d. h. pro die c. 0·5 g. Kupfersulfat = 120 mg. Kupfer. Sie erbrachen oft nur die ersten Dosen und behielten das übrige bei sich. Ja in einzelnen Fällen verordneten Aerzte bis zu 1 g. Kupfersulfat = 250 mg. Kupfer an einem Tage. Niemals wurde irgend ein Schaden davon gesehen, selbst wenn nur wenig gebrochen wurde.

Die kleinste genau bekannte Dose eines reinen Kupfersalzes, von der ich eine ernstere Affection eines Erwachsenen in der Litteratur sichergestellt beschrieben finde, ist etwa 5 g. Kupfersulfat = 1,200 mg. Kupfer; einmal soll ein Kind an 1·2 g. Kupferchlorid, d. h. 560 mg. Kupfer gestorben sein, was bei der ätzenden Wirkung des diesmal ziemlich concentrirt genommenen Präparates wohl glaublich erscheint. Aber grade zur Einführung concentrirter Lösungen ist *im Haushalt* am wenigsten Gelegenheit gegeben. Dass es, wie es eine Idiosynkrasie gegen Erdbeeren, Krebse, Morphium, Ammoniakgas, schweflige Säure und viele andere Stoffe giebt, auch eine solche für Kupfer gelegentlich einmal geben kann, soll nicht geleugnet werden; solche Abnormitäten werden aber ohne jeden Einfluss auf unsere Reflexionen bleiben müssen. Crog hat Personen beobachtet, die angeblich 30 mg. Kupfersulfat = 8 mg. Kupfer auf einen ganzen Tag vertheilt nicht vertragen, ja, nach einer Angabe Blodig's hat Letzterer Intoxicationssymptome durch blosses Aetzen der Conjunctiva mit Kupfersulfatcrystallen beobachtet.

IV.

Die Vermuthung, dass einzelne Kupfersalze vielleicht schädlicher wirken als die anderen, entbehrt jedes Beweises. Es sind bisher von den einzelnen Autoren und mir selbst Acetat, Sulfat, Carbonat, Citrat, Succinat, Chlorid, von mir speciell vielfach Butyrat, Oleat, Lactat geprüft worden, ohne dass eine wesentliche Differenz der Wirkung bestände. Aber auch die verschiedenen Versuche der Autoren mit Kupferalbuminaten können nur die Ueberzeugung verstärken, dass eine specifische Wirkung irgend welcher Kupfersalze, wenn sie nicht an giftige Säuren gebunden sind, nicht besteht.

In einem Versuch, in dem ich selbst 132 Milligramm Kupfer in 200 Gramm selbst grüngefärbter Erbsen verzehrte, wurde bei dem Essen wenig unangenehmer Geschmack, aber etwa $\frac{1}{2}$ Stunde anhaltender kupferiger Nachgeschmack bemerkt; nach dreistündiger abwechselnd schwerer und leichterer Nausea trat ein zweimaliges heftiges Erbrechen, dann aber vollkommenes Wohlbefinden ein, vier Stunden später wurde mit Appetit zu Abend gegessen.

V.

Die Litteratur enthält keinen einzigen Fall von akuten Vergiftungen durch kupferhaltiges Brot oder Conserven, obwohl, wie wir sahen, auf diesem Wege am Leichtesten grosse Kupfermengen eingeführt werden und sicherlich schon häufig eingeführt worden sind, namentlich solange die Controlle nicht streng und die Verwendung des Kupfers zu diesen Zwecken in manchen Ländern allgemein war.

Dagegen sind eine Menge Fälle gut oder schlecht beschrieben, in denen schwerste, ja tödtliche Erkrankungen eintraten, nachdem eine

Suppe, ein Ragout oder drgl. verzehrt war, das nachher als kupferhaltig erkannt wurde. Wenn überhaupt die Untersuchung auf Kupfer quantitativ ausgeführt wurde, so ergab sie in diesen Fällen niemals Zahlen, die es auch nur entfernt darthun, dass einer der Erkrankten auch nur 150–200 Milligramm verzehrt habe; gewöhnlich liess sich nur die Aufnahme von 20–50 Milligramm Kupfer wahrscheinlich machen.

Da sich weder viel Kupfer noch die Anwesenheit besonders giftiger Kupferverbindungen in den mit Kupfergeschirren bereiteten Speisen nachweisen lässt, so drängt sich dem Unbefangenen die Annahme auf, dass vielleicht neben den Kupferverbindungen andere Gifte vorhanden gewesen sein möchten.

Die Thatsache, dass in vielen der sogenannten Kupfervergiftungen nach Einführung kleiner Kupfermengen neben Brechdurchfällen die verschiedensten nervösen Störungen wie Kopfweh, Zittern, Manie, Scorbut, bei den Sectionen schwere geschwürige Magendarmentzündungen angegeben werden, spricht auch sehr gegen die Bedeutung des Kupfers.

VI.

Die ökonomischen "Kupfervergiftungen" sind meist durch Nahrungsmittel bedingt, die *längere Zeit* in Kupfer aufbewahrt waren; nehmen wir nun an, dass dabei gebildete Bacterienstoffwechselproducte die eigentliche Schädlichkeit darstellen, so erscheint die grosse Mehrzahl der "Kupfervergiftungen" in ganz anderem Licht. Jetzt ist ohne weiteres verständlich:

1. warum so wenig Kupfer zur schweren Vergiftung nöthig erscheint;
2. warum die stets sehr kupferarme Fleischbrühe, Ragouts u. dgl. so oft Kupfervergiftungen bedingen, dagegen stark kupferhaltige Conserven noch nie ernstere Erkrankung erzeugen;
3. warum die Krankheitsbilder so verschieden sind, oft von schweren nervösen Symptomen begleitet;
4. warum so häufig bei dunkeln Vergiftungsfällen ganz die Symptome der sogenannten "Kupfervergiftung" auftreten, ohne dass eine Spur Kupfer nachgewiesen werden konnte, so sehr man auch nach dieser bequemen Erklärung für die Störung gesucht hatte;
5. warum mit der zunehmenden Kenntniss von den Ptomaïnvergiftungen die Kupfervergiftungen in der Litteratur immer seltener werden.

Es soll damit nicht gesagt sein, dass nicht auch andere organische oder anorganische Gifte gelegentlich einer Kupfervergiftung vorgetäuscht haben.

Es möge mir gestattet sein, an einigen älteren und neueren Fällen meine Ansicht über die angeblich bewiesene Bedeutung der Kupfergeschirre zu zeigen.

Johann Peter Frank erzählt in seinem vorzüglichen "System einer vollständigen medizinischen Polizei, 1783," neben einigen anderen

Alarmgeschichten über die Giftigkeit des Kupfers im Eifer einen Fall, in dem die Väter des Oratoriums zu Angers alle nach dem Genuss eines Ragouts sehr schwer erkrankten, welches in einem völlig reinen *gut überzinnten kupfernen* Gefäss nur aufgewärmt worden war. Wer zweifelt hier an einer Fleischvergiftung?

Navier (1772) berichtet von schweren Vergiftungen an 7 Personen einer Familie durch einen Kuchen und Ragout und Suppe. Es soll hier ein kupferner Schaumlöffel, mit dem das zum Kuchen verwendete Butterschmalz abgeschäumt wurde und der auch zum Abschäumen der Suppe Anwendung fand, an dem Unglück schuld gewesen sein. Diese Erklärung ist einfach grundlos, die Möglichkeit einer nennenswerten Kupfereinführung ausgeschlossen,—eine Ptomaïnvergiftung durch das Fleisch, eine Barytvergiftung oder Mehlptomaïnvergiftung durch den Kuchen unendlich wahrscheinlicher.

Die berühmte oft citirte von Pleischl und Heller 1847 im Krankenhaus zu Wien beobachtete "Kupfermassenvergiftung" kann ich auch nicht auf Kupfer beziehen. Es erkrankten 130 Personen, von denen neun theils unter den Symptomen der Manie, theils des Scorbuts zu Grunde gingen! Die Ulcerationsprocesse im Darmkanal wären nur bei sehr grossen ätzenden Kupfermengen auf letzteres zu beziehen; so bildet die ganze Erkrankung das schönste Pendant zu den Fleischvergiftungen der neueren Zeit, wenn auch Heller etwas Kupfer in den Speiseresten und im Erbrochenen der Kranken fand.

Für die beiden neuesten von Mair beschriebenen tödtlichen Kupfervergiftungen (Friedreichs Blätter 1887) kann ich auch durchaus nicht den Beweis, dass das Kupfer die Todesursache darstelle, als geliefert ansehen. Beide Fälle sollen durch Verwendung von Kupfergeschirren zu erklären sein; der eine könnte ebensogut eine Ptomaïnvergiftung, der andere sehr interessante, bei dem 4 Personen in wenigen Stunden starben, eine Kohlenoxydvergiftung darstellen.

VII.

Lässt sich durch das Bisherige darthun, dass beim gesunden Erwachsenen schwere akute ökonomische Kupfervergiftungen kaum eintreten können, so mag gerne zugegeben werden, dass das Erbrechen, das auf die Einnahme grosser Dosen folgt, gelegentlich bei geschwächten Individuen, namentlich schwachen Greisen, zufällig eine schwere Störung der Herzfunction, Collaps u. dergl. auslösen kann. Hier hat das Kupfer aber keineswegs specifisch, sondern nur wie ein einfaches Brechmittel gewirkt.

VIII.

Es handelt sich nun noch um die Frage der chronischen Kupfervergiftung. Die Zeiten, in denen die übertriebenen kritiklosen Schilderungen von der Häufigkeit chronischer Kupfervergiftungen

namentlich bei Fabrikarbeitern geglaubt wurden, sind längst vorüber. Die Gastropathia cuprica febrilis, die Colica aeruginis, die Kupferlähmung sind jetzt entweder als seltene Krankheiten erklärt—oder der Zusammenhang derselben mit dem Kupfer wird gar ganz geleugnet, und Blei, Zink, Cadmium, Kohlenoxyd und andere chemische eventuell auch physikalische Schädlichkeiten als wahre Krankheitsursache betrachtet.

Eigene Erfahrungen habe ich an Kupferarbeitern keine sammeln können, kann aber durch die Güte des ausgezeichneten Kenners der Gewerbekrankheiten, Medicinalrath Dr. Merkel in Nürnberg, mittheilen, dass derselbe trotz der grossen Broneeindustrie in Fürth, bei der die Arbeiter von Broneestaub ganz vergoldet und versilbert sind, *nie* eine Kupfervergiftung gesehen hat. Hirt's Erklärung der Kupferkolik als akute Kupfervergiftung bei unreinlichen Kupfer- (Grünspahn-) Arbeitern erscheint mir recht annehmbar, um einen Theil der Fälle, wo man mit der Annahme einer Vergiftung durch andere Metalle nicht auskommt, zu erklären. Für einige wenige in der Litteratur immer wieder abgedruckte Fälle : Kupfervergiftung bei einem Buchbinder durch Vergolden der Bücherrücken mit unächtem Gold, bei einem Manne durch ein in Kupfer gefasstes Gebiss, ist nur die Annahme einer besonderen ganz räthselhaften Idiosynkrasie möglich, wenn nicht auch hier irgend eine falsche Deutung vorliegt.

Von einer chronischen Vergiftung durch kupferhaltige Nahrungsmittel (Brot, Conserven) enthält die Litteratur keinen einzigen gut beobachteten Fall, dagegen ass Galippe experimenti causa 14 Monate mit seiner Familie blos in Kupfer zubereitete und häufig darin erkaltete Speisen ohne jeden Schaden.

Ich selbst habe, um mir über die älteren Erfahrungen von Toussaint, Du Moulin u. A., an Thieren und Menschen ein objektives Urteil zu bilden, langdauernde Fütterungsversuche mit meinen Schülern an 6 Kaninchen, 4 Katzen und 1 Hunde angestellt. Es wurden dabei, nachdem die Thiere sich in einigen Tagen an den Kupfergehalt der Nahrung durch kleine Dosen (10–30 mg. Kupfer) gewöhnt hatten, meist Dosen von 50, häufiger noch von 100 mg. Kupfer gefüttert und die Versuche 2–4, einmal 6 Monate fortgesetzt.

Es wurde Sulfat, Acetat, Chlorid, Oleat, Butyrat, Lactat ohne jeden Unterschied der Wirkung verwendet.

Die Salze wurden stets vollkommen mit der Nahrung gemischt und ihre Aufnahme controlliert. Abgesehen von gelegentlichem Erbrechen und bei der Section einigemal entdecktem Magenkatarrh waren die Thiere ganz wohl, speciell auch die Nieren gesund. Ein Theil der Thiere zeigte sogar beträchtliche Gewichtszunahme. Nervöse Symptome, Krämpfe, Lähmungen, Diarrhoen, Obstipationen wurden nie beobachtet. Dagegen wies die Analyse der Organe eine bedeutende Kupferresorption nach, die Lebern der Katzen enthielten durchschnittlich 12 mg. Kupfer, auch in den übrigen Organen war etwas mehr Kupfer als bei akuten Intoxicationen zu finden.

Trotz der Versuche von Toussaint und Galippe am Gesunden und so vieler interessanter Erfahrungen an lange Zeit mit hohen Kupferdosen behandelten scrophulösen und nervenkranken Personen, erschien es mir erwünscht auch am gesunden Menschen nochmals Erfahrungen zu sammeln.

Es nahmen daher 2 meiner Schüler nochmals täglich in Bier kleine Kupfermengen, der eine als Sulfat, der andere als Acetat :

Herr M	50 Tage	10 mg.	Cu	= 39 mg.	Kupfersulfat
dann	30 „	20 „		= 78	„
Herr K	3 „	5 „		= 16 mg.	Kupferacetat
	10 „	10 „		= 32	„
	1 „	15 „		= 48	„
	19 „	20 „		= 64	„
	18 „	30 „		= 96	„

Beide Herren beobachteten nicht ein einziges mal die leiseste Störung an sich weder während des Einnehmens noch nachher. Ich wählte die Dosen absichtlich kleiner, als sie zu therapeutischen Zwecken genommen zu werden pflegten, da ich auch jede Magenbelästigung vermeiden wollte.

Soweit man nach 2- bis 3-monatlicher Versuchsdauer einen Schluss ziehen kann, muss ich mich unumwunden dahin aussprechen : Die Versuche am Menschen mit kleinen Kupferdosen sprechen auch bei uns absolut gegen die Möglichkeit einer chronischen Kupfervergiftung, durch die im Haushalt vorkommenden Mengen.

Es sei mir noch gestattet, aus einem schon recht umfangreichen und mühsam gewonnenen Zahlenmaterial hier noch einige theoretisch interessante Daten vorläufig mitzutheilen : Von mittleren Kupferdosen, die man einnehmen lässt, werden einige Procent resorbiert (von kleinen Dosen mehr, von grossen weniger) ; leichte Magenanätzung scheint ohne Bedeutung für die Resorptionsgrösse ; die grösste Menge des offenbar vorwiegend aus dem Darme resorbierten Kupfers wird vorübergehend in der Leber deponirt, der Hauptausscheidungsweg für das Kupfer scheint beim Hunde die Leber, beim Kaninchen der Darm, beim Menschen die Niere.

Für den Menschen haben wir speciell durch zahlreiche sorgfältige Analysen dargethan, dass nach Einnehmen von 30 mg. Kupfer im Harn in 3 Tagen zusammen circa 4–5 mg. erscheinen, über die Ausscheidung durch Darm und Galle lässt sich beim Menschen natürlich nichts weiteres sagen.

IX.

Von diesen Erwägungen geleitet, ist eine directe Schädigung akuter oder chronischer Art von *den* Kupfermengen nicht zu befürchten, wie sie durch maassvolle und kunstgerechte Reverdissage, Brotbereitung mit Kupfer, und etwas sorglose Benützung kupferner Gegenstände im Haushalt in den Körper gelangen; dagegen können durch grob

nachlässig hergestellte Conserven oder Brot und absolut nachlässig behandelte Kupfergeschirrc recht wohl Erbrechen, vielleicht auch einmal Brechdurchfall, aber kaum *mehr* entstehen.

Die Hygiene wünscht ein Verbot der Vcrwendung von Kupfer zur Färbung von Gemüseconserven, weil :

a. die Gefahr des Missbrauchs (des nachlässigen Zusatzes zu grosser d. h. schädlicher Mengen) vorliegt;

b. weder Haltbarkeit noch Geschmack der Conserven dadurch gewinnt;

c. kein Grund vorliegt die Conserven grüner zu färben als die frisch gekochten Gemüsc.

Die Hygiene hat also ein Interesse daran, den nutzlosen Kupferzusatz zu Gcmüsen überall zu verbieten; der Uebertreter dieser Vorschrift wird aber nur dann "wegen einer möglicherweise eintretenden "Beschädigung der menschlichen Gesundheit" zu bestrafen sein, wenn wirklich bedeutende Mengen Kupfer in die Gemüse eingeführt sind. Der Zusatz *kleiner* Mengen, etwa 20–30 mg. pro Kilo, wird nur aus nicht hygienischen Gründen, wenn man will "als scheinbare Verbesserung," als "Täuschung über die Qualität" u. dergl. zu bestrafen sein.

Der Zusatz von Kupfer zu Brot ist stets absolut zu verbieten, weil:

a. die Gefahr des nachlässigen Zusatzes zu grosser gesundheitsschädlicher Mengen vorliegt;

b. verdorbenes, unter Umständen schädliches, verdorbenes Mehl wieder backfähig wird;

c. ein vermehrter Wasserzusatz (6–7 %) möglich wird.

Kupfergeschirre sollen nicht zum Aufbewahren fetter, saurer oder gesalzener Speisen dienen.

Damit ist Alles geschehen, um auch die leichten Kupferschädigungen auszuschliessen.

Die gerichtliche Medicin hat die Pflicht, viel mehr als dies heute noch geschieht, bei angeblichen schweren Kupfervergiftungen durch Speisen quantitative Ermittelungen anzustellen, um darzuthun, ob denn wirklich allermindestens 200 Milligramm Kupfer von dem Vergifteten genossen sind. Lässt sich dieser Beweis nicht führen, so ist an eine Kupfervergiftung bei einem Erwachsenen nicht zu denken, vielmehr durch Anamnese und Analyse nach Ptomaïnen oder Toxalbuminen zu fahnden. Für eine tödtliche Kupfervergiftung am gesunden Erwachsenen sind nach unseren Kenntnissen mindestens 1200 mg. Kupfer nöthig.

DISCUSSION.

The President briefly recapitulated the chief points of Professor Lehmann's Paper in English, and pointed out the great value of the results therein described.

Mr. Goodfellow remarked that, having had occasion within the last three years to examine a large number of samples of English bread for adulterants, he was enabled to say that no case of adulteration with copper sulphate had come under his notice. He had, however, examined seven specimens of Dutch bread, and had found traces of copper sulphate in four cases.

Mr. Cassal said that copper had not been found in bread by British public analysts, so far as he was aware, since the passing of the "Sale of Food and Drugs Act, 1875." If it ever existed as an adulterant of bread, it must have been some time before the passing of that Act. There had recently been a conviction at Glasgow for selling tinned peas containing copper.

Dr. H. G. Colman asked Professor Lehmann whether he believed that tin, as well as copper, had not the great poisonous effect usually ascribed to it. Most of the cases of poisoning from tinned meats which had been ascribed to tin-poisoning really appeared to be due to ptomaines.

Dr. W. J. Russell, F.R.S., believed that the bad character of copper had been gained owing to the ease with which it is detected in small quantities in chemical analysis, and alluded to the curious fact that considerable quantities of copper were contained in the two red tail-feathers of the Touracon.

Professor Lehmann, in reply to Dr. Colman, stated that tin, when taken in small quantities for a length of time, had, undoubtedly, an ill effect upon the system, but believed that all the supposed acute cases of tin-poisoning were in reality caused by ptomaines.

The Action of Water on Lead.

BY

J. H. Garrett, M.D., D.P.H.

The subject of the action of water on lead has a special hygienic interest on account of its resulting in the contamination by lead of drinking-water.

In the Gulstonian Lectures, delivered in the early part of the present year before the Royal College of Physicians of London, Dr. Thomas Oliver has treated the subject of lead poisoning in an exhaustive manner, and to his treatise reference can be made for information upon the pathological effects likely to accrue from imbibition of this metal and its salts.

The chemical aspect of the question, which at present concerns us, has received the attention of several experimenters, but the want of agreement noticeable in their results has led to a confusion rather than to a settlement of the matter. I venture to suggest that this has been mainly due to the different ways in which the experiments have been conducted, and to the bias in favour of the acid, which is sometimes con-

tained in natural waters that act on lead, being in some way the cause of the action.

By the observations I have made upon the action of a great many waters, I am convinced, and cannot think there is room for doubt, that the primary action of water on lead is in every case a process of oxidation. Thus, the invariable result of putting lead into contact with water neutral or faintly alkaline in reaction, such as most distilled waters, is the production of a colourless crystalline oxyhydrate of lead that is almost insoluble in pure water. I have recently had under examination numerous samples of soft waters from the Devonshire rivers, &c., and have found that they act upon lead in a manner practically identical with the action of distilled water, and a similar effect may commonly be obtained from rain water. In each case solid oxyhydrate of lead is rapidly produced, and falls off the lead as it is formed, leaving a fresh surface to be acted upon. The air being admitted to the surface of the water, this action is continuous, lasting for weeks or months, or until the lead is buried in the deep layer of oxyhydrate produced.

With the action of these neutral or faintly alkaline waters, let us contrast the action of a decidedly acid water. Naturally acid waters are found in connexion with peat and otherwise, but the composition of the acid which these peat waters contain is at present unknown. When one of these acid waters is placed in contact with lead we get a clear solution of lead salt as an immediate result; but, doubtless, the lead is oxidized before being dissolved by the acid. The amount of acid present of course determines the amount of lead that can be dissolved. The action does not necessarily stop here, however, but the oxidation of the lead may continue beyond the point of saturation of the acid, and the extra oxide formed, or a part of it, combining with the neutral salt in solution forms an oxysalt. This oxysalt being less soluble than the neutral salt, less lead is now contained in solution; a portion of that at first dissolved now forming part of the deposit that lies upon the bottom of the vessel or upon the surface of the lead. When the acid in the water is very small in quantity the usual production of oxyhydrate of lead is only delayed for a short time. When a much more appreciable quantity of acid is contained in the water, the oxysalt which is thrown out of solution and deposited, or formed, upon the surface of the lead, tends to adhere firmly, and covering the lead protects it and thus brings the action to a termination. By a very careful neutralisation of the acid, the production of solid oxyhydrate may be made to commence immediately, just as it does in waters that are naturally neutral or nearly so. The oxyhydrate of lead itself gives the water an alkaline reaction, and the reaction of every water that is acting on lead is therefore destined to become alkaline ultimately, the only factor necessary for the continuous oxidation of the lead being a constant supply of oxygen.

Waters which are decidedly alkaline by reason of containing considerable quantities of a carbonate, such as calcium carbonate, including

those that deserve in any degree the title of hard waters, are prevented from acting on lead by the formation upon the surface of the metal of a closely fitting insoluble coat or film, which is presumably a basic carbonate of lead. The carbonic acid which ordinarily acts as a solvent to the carbonate of lime in hard waters, does not leave the carbonate of lime to dissolve carbonate of lead; but unusual waters may exist in which there is a very large excess of carbonic acid gas over that required to hold in solution the calcium carbonate, and the formation and solution of carbonate of lead may then be expected. Such a water must be included amongst the acid waters, and there is no acid water that so well exemplifies the effect of the continued oxidation at the surface of the lead, in causing the ultimate precipitation of the soluble lead salt at first formed, as distilled water into which carbonic acid gas has been passed. As will be seen in the following table, the solution becomes stronger until it contains lead in the proportion of 2·8 millegrammes per litre; but after 20 hours' further exposure the strength is reduced to ·14 millegrammes per litre.

Table showing the Amount of Lead dissolved by Distilled Water into which CO_2 has been passed.

Time exposed.	Lead in Solution.
3 hours	·94 millegrammes per litre.
10 „	2·8 „ „
30 „	·14 „ „

It has been stated by some authors that carbonic acid gas dissolves lead; by others, that it coats lead and prevents the action of water upon the metal. It does both; first the one, and then the other. For carbonate of lead is first dissolved by excess of CO_2; but this excess of CO_2 is presently neutralised by further production of oxide of lead. A great part of the lead at first dissolved is withdrawn from solution, and a basic carbonate is formed upon the surface of the lead which, protecting it from the water, causes cessation of action. The coat which carbonic acid gives to lead in this way is a soft white fur, quite different from the closely fitting film that is formed upon it when an alkaline carbonate is contained in the water. A fur similar in appearance, composed of basic salt, covers the lead as an ultimate result of the action of waters containing other acids, such as nitric, hydrochloric, or sulphuric, which in limited proportion have been purposely added to the water, or the acid naturally contained in peaty waters when it exists in them in sufficient quantity. The fact of a water containing certain neutral salts other than carbonate, such as sulphate, also leads to the formation of a similar fur upon the surface of the lead, a reaction between the oxyhydrate of lead and the sulphate of calcium, &c. evidently taking place. The presence of sulphate, chloride, &c. causes more lead to be retained in solution, and ammonia salts do the same thing in a particular degree, especially nitrate of ammonia. Sulphate diminishes the rate of production of oxyhydrate of lead, or puts an end to its production altogether by

clogging the surface of the lead with basic salt of slight solubility that does not fall off the surface of the metal as do the fine crystals of the oxyhydrate itself. The presence of chloride appears to increase the rate of oxidation of lead. Phosphate and silicate have some power in causing a closely fitting insoluble film to be formed on the surface of the metal which has influence in protecting it from further action of water; but the protective coat afforded by these salts does not form so quickly and perfectly as in the case with that formed by carbonate.

The rate of action of water on lead, whether the water be acid or faintly alkaline, is increased in a marked manner by increase of temperature, perhaps up to 70° C.; but above that temperature a comparatively slight and limited action takes place. In my experiments I have got the most marked results at about 50° C.

I am desirous of making it plainly understood that it is in waters that are nearly neutral in reaction that the production of lead salt occurs with greatest rapidity and continues with the least interruption; and lead may generally be found in such waters when they are conveyed through leaden pipes. It is not dissolved, but exists in a state of suspension. The minute crystals of oxyhydrate lend themselves very readily to suspension, and when suspended in a water may be easily overlooked, unless the water be critically examined in a good light. The lead when existing in water in this condition, has no doubt sometimes been taken to be dissolved. The practical effects are much the same as if it were dissolved; but it is well to make the distinction in considering the cause of the action of water on lead.

The action consisting primarily and chiefly in the oxidation of the metal, we are at the root of the matter when we begin to consider whence and how the oxygen is derived. What are the possible sources of oxygen? *a.* The free oxygen that is dissolved in the water. *b.* Oxygen that may be derived by decomposition of water, either by the lead itself displacing hydrogen, or by an electrolysis due to voltaic action resulting from the fact of common sheet and pipe lead being invariably alloyed with small quantities of other metals. *c.* Oxygen derived by reduction of the nitrates and nitrites, or other forms of oxidised nitrogenous matter, which occur in most waters to a greater or lesser extent.

If a water be obtained that has not the power of acting on lead, even though it contain no carbonate, &c. to obstruct the action (and such a water is occasionally met with) no amount of aëration will cause the action to start, or increase it where it only occurs in a slight degree. If a distilled water, which has been found to act on lead in the cold with rapid and continuous production of oxyhydrate, be placed in a platinum dish and boiled for five minutes, we may take it for granted that the whole of the free oxygen is dissipated. Now if without allowing the water to cease boiling we drop in pieces of clean lead, there should be no lead salt formed provided the action be wholly due to free oxygen. But a limited, yet decided quantity of lead salt is formed, giving the water

an opalescence and a flocculent deposit. This initial action cannot be due to free oxygen. But if it be thus proved that action can take place when the absence of free oxygen is assured, it is quite as easy to prove that a *continuous* oxidation of the lead cannot take place unless air be admitted to the surface of the water. A water which acts on lead with production of oxyhydrate being placed in an appropriate vessel along with pieces of clean lead, melted paraffin wax or oil is poured over the surface of the water, and the air is thus shut out. A check experiment is at the same time made with water and lead in the same proportions, but with the air freely admitted to the surface of the water. In the former, action occurs and proceeds for a time, and then abruptly comes to an end. In the latter, similar action occurs, and the two keep pace for a time equally with each other; but in this, the action continues after it has ceased in the other, so that at the end of a week the lead salt formed in it is vastly greater than that which has been formed in the one from which air is excluded. From this observation we are forced to the conclusion that whatever may be the initial cause of the action, the continuation of it beyond a certain point is certainly dependent upon absorption of oxygen from the air.

The fact of the action requiring for its continuance, but not for its commencement, a supply of air, proves of itself that the action is not due to a decomposition of water either by a simple displacement of hydrogen by lead, or by electric influence. Besides this, at common temperatures, the action of water on lead does not result in any evolution of hydrogen, and it would not be possible for decomposition of water to proceed for any length of time without hydrogen being evolved. In regard to the production of an electric current by reason of the impurity of the lead, samples of pure metal, that is, as pure as could be obtained by igniting either of several carefully prepared plumbic compounds in a porcelain crucible, were found to have an action upon water precisely similar to the commercial metal. Silver is the metal that is most likely to exist in lead in such quantity as to cause any effect of practical importance in the action of water upon it. The minute traces of copper and other metals that may occur can have little appreciable effect. I have made experiments into the effects upon the oxidation of lead of coupling different metals along with it before immersing it in the water. Strips of foil of the several metals, of equal surface, were taken, and strips of lead were coupled with similar strips of each of the other metals by merely hooking and bending their ends together, so that the two metals formed a ring, half of which was of lead and half of the other metal. A check experiment being made with one of the pieces of lead-foil alone, the amount of lead salt formed from the lead alone, could be compared with that formed by each couple. The lead used was a thick lead-foil, supplied by Messrs. Hopkin and Williams, of Hatton Garden, which was stated to be pure lead. Some of the other metals were supplied by the same firm in the form of thick foil. The following results were obtained. The experiments were performed simultaneously, and equal measures of water were used. Temperature averaged about 17° C.

Experiment I.—The water used was distilled water with a slightly alkaline reaction. The metals were in the water 12 hours, being wholly immersed.

Metals employed.	Relative Amount of Lead converted into Lead-salt.
Lead alone	100
Lead and silver	120
Lead and copper	108
Lead and iron	100
Lead and aluminium	16
Lead and tin	14
Lead and zinc	6

Thus the silver and copper coupled with lead caused a slight increase of action on the lead in this alkaline water, whilst aluminium, tin, and especially zinc, caused a marked diminution. The silver and copper did not themselves appear to be affected, but some oxidation of the iron and other metals took place.

Experiment II.—The water used was distilled water, made very faintly acid with acetic acid. The metals were in the water three hours, wholly immersed as before.

Metals employed.	Relative Amount of Lead converted into Lead-salt.
Lead alone	100
Lead and copper	150
Lead and silver	133
Lead and iron	7
Lead and zinc	5
Lead and aluminium	0
Lead and tin	0

Coupling with aluminium and tin wholly prevented the oxidation of lead in this water whilst coupling with copper and silver again increased it. The silver and copper themselves appeared unaffected, but the other metals could be detected in the respective waters.

Experiment III.—The water used was as in last experiment, but was made more strongly acid with acetic acid. It contained, in fact, about ½ per cent. strong acetic acid. The metals were immersed in the water 12 hours.

Metals employed.	Relative Amount of Lead converted into Lead-salt.
Lead alone	100
Lead and aluminium	7
Lead and tin	7

Experiment IV.—The water was a peaty water from Dartmoor, with a naturally acid reaction. The metals were immersed in the water three hours.

Metals employed.	Relative Amount of Lead converted into Lead-salt.
Lead alone - - - -	100
Lead and silver - - -	300
Lead and copper - - -	150
Lead and tin - -	70
Lead and zinc - - -	70

With this water the zinc and tin did not appear to prevent action on lead in such a marked way as in previous experiments. The action was, however, increased to a greater extent by copper and silver.

It is a rare thing to meet with a water that is absolutely nitrate free; and as lead reduces nitrate at common temperature when contained in solution in a water, however minute a proportion be present, we have here an undeniable source of oxygen. Every nearly neutral water that acts on lead with production of crystals of oxyhydrate, and every naturally acid water that acts on lead with solution of the oxide, gives evidence of containing nitrite after the action has taken place. As the water did not contain nitrite in the first place, or if it contained nitrite the quantity is now increased, we are right in assuming that it has been produced by reduction of nitrate by the lead. In the hundreds of experiments that I have made upon the action of water on lead, in no case where the ordinary action has occurred have I failed to obtain ample proof of the presence of nitrite after the action. But although lead reduces nitrate to nitrite (and when air is excluded probably to hypo-nitrite) it never reduces it entirely to ammonia at common temperature. The reduction apparently does not take place with sufficient rapidity for this to happen; and unless water be decomposed, there is no hydrogen to form ammonia with the nitrogen of the nitrate. When there is free admission of air the nitrite is reoxidised by the oxygen of the air as fast as it is reduced by the lead.

The main action of water on lead is therefore due to the presence in the water of a nitrate (or some partially oxidised organic nitrogenous compound which admits of being reduced by the lead and reoxidised by the air giving the reaction of nitrite when reduced). The continuation of action observed to take place in a nearly neutral water, where oxyhydrate of lead is produced for weeks together, is due to nitrite acting as an oxygen carrier between the air and the lead. The rate of action is increased when copper, silver, and other metals are in contact with the lead beneath the water. The rate is diminished when zinc, tin, and other metals are similarly in contact with it, these metals suffering oxidation in preference to the lead.

DISCUSSION.

Dr. Rideal asked whether the reduction of nitrate to nitrite took place in the experiments cited by Dr. Garrett, only when a "couple" of two metals was employed; and if the reduction was continued to ammonia; as with a copper-zinc couple the presence of nitrite, and therefore of an oxygen carrier, would be prevented?

Mr. W. R. Maguire (Dublin) said that in Dublin the public water supply from the Vartry River is a very pure one, resembling the Glasgow water from Loch Katrine. Fifteen years ago it was discovered that lead pipes and cisterns were attacked by this water, and the Corporation, in order to prevent lead poisoning, ordered that all lead pipes for water should contain 3 per cent. of tin. This had been carried out for 15 years without any case of lead poisoning attracting attention. Sir Charles Cameron found that small carp placed in the lead tanks showed signs of paralysis which so cramped their bodies that it caused them to miss their food as they darted at it. In tanks made of lead alloyed with 3 per cent. of tin this did not occur. Mr. Maguire inquired whether this alloy would give absolute security against lead poisoning. Small iron pipes could not be used to convey Vartry water, as the pipes were choked within a few months.

Dr. Russell mentioned a case in which a very pure water had dissolved a large amount of zinc from the containing tank.

What is the Importance of Magnesia in Drinking Water?

BY

Percy F. Frankland, Ph. D., B. Sc. (Lond.), F.R.S., Professor of Chemistry in St. Andrews University, Dundee.

It must be confessed that in spite of the enormous amount of attention which has for years been devoted to the chemical analysis of drinking water, we are still lamentably ignorant of the precise hygienic importance of the mineral constituents which analysis reveals. Indeed the diversity of opinion regarding these mineral substances is far greater than concerning the more obscure and less easily handled organic matters of drinking-water. Thus some authorities actually prefer waters containing a very considerable proportion of mineral matters, others object to such waters, and others again regard the matter with complete indifference. Phosphatic calculi, goitre, and cretinism have been by some referred to waters containing lime and magnesia salts, whilst others have adduced evidence that such disorders are wholly unconnected with hard water. This question of the relative fitness of hard and soft water for drinking purposes was submitted to

investigation by the Rivers Pollution Commission of 1868, who, after devoting no less than 16 pages to a critical review of the evidence before them, leave the matter in the supremely unsatisfactory condition indicated by the following words:—

> "We are, therefore, of opinion that whilst waters of excessive hardness may be productive of calculous and perhaps other diseases, soft and hard waters, if equally free from deleterious organic substances, are equally wholesome."

The said Commissioners are, however, entirely silent on the subject of magnesia; indeed amongst the innumerable analyses of potable water which occur in their Sixth Report there is, I believe, only one in which the magnesia is recorded at all. This is in the case of the water supplied from a deep well in the magnesian limestone to Sunderland, which is said to contain 3·96 parts of magnesia (MgO) per 100,000.

Within recent years there has however, arisen in certain quarters in this country a belief that magnesia when present in more than a very limited quantity is objectionable, and I am acquainted with at least one case in which an otherwise unimpeachable water was discarded in consequence of its containing a few grains of magnesia per gallon.

This view is the more open to question in consequence of the very limited information which is available concerning the proportions of magnesia which are commonly met with in British potable waters. The determination of magnesia is one of the most laborious which occur in water examination, and is consequently but rarely undertaken by water analysts; from time to time, however, I have had occasion to determine the magnesia in waters which have been submitted to me, and I think that it may not be without interest to place on record some of the results which I have obtained more especially on this occasion, so that the proportions met with in British waters may be compared with those found on the Continent where the magnesian formations are much more largely represented.

In the accompanying table, pp. 84 and 85, I have recorded the results of analysis of a number of typical samples, which serve to illustrate the proportions of magnesia found in the supplies obtained from some of the more important water-bearing strata of great Britain.

These analytical results show that the calcareous waters derived from the chalk contain only a very small proportion of magnesia, and that even in the highly saline waters obtained from the chalk below the London Clay the amount is also very moderate, only distinctly greater than in the case of the normal chalk waters.

The proportion of magnesia, again, is considerably greater in the water from the lias, as represented by the wells at Wellingboro', whilst the largest proportions were found in waters from the magnesian limestone and new red sandstone.

[ANALYTICAL TABLE.]

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

Description - (I.).	Total solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Remarks.
Spring water from Newark-on-Trent, used for brewing purposes - (I.)	257·05	·046	·013	0	·465	·478	2·9	17·2	162·8	180·0	
(II.)	Fe_2O_3 and Al_2O_3		CaO	**MgO**	Na_2O	SO_3	N_2O_5	SiO_2	—	—	
	·14		82·89	**14·74**	4·68	131·51	1·79	·98	—	—	
Pontefract water supply from Magnesian limestone. (I.)	88·84	·035	·010	0	3·315	3·325	5·9	16·6	37·2	53·8	Total **MgO = 9·23.**
Well in bunter beds of new red sandstone at Sandiacre, Derbyshire. (I.)	45·04	·097	·037	·021	·094	·148	2·0	19·5	18·7	38·2	Total **MgO = 7·05.** Total CaO = 10·78.
Spring at Matlock Bath, Derbyshire. (I.)	47·84	·021	·002	0	·030	·032	4·1	18·8	15·3	34·1	Total **MgO = 4·08.** Total CaO = 11·37.
Bore-hole in alluvium near River Derwent, Matlock Bath. (I.)	24·44	·117	·048	·020	0	·064	·9	9·0	8·2	17·2	Total **MgO = 2·53.** Total CaO = 5·60.
Boring in new red sandstone at Gainsborough, Lincolnshire. (I.)	49·97	·028	·008	0	0	·008	2·0	16·8	18·6	35·4	
(II.)	·19		11·94	**5·97**	2·84	16·62	0	·94	—	—	
Waters from Malvern:											Total:—
No. 1. - - (I.)	27·48	·092	·024	0	·668	·692	1·9	11·6	9·6	21·2	**Magnesia = 4·09.**
No. 2. - - (I.)	8·52	·045	·016	0	·354	·370	1·2	0	4·3	4·3	Ditto = **·75.**
No. 3. - - (I.)	12·56	·033	·014	0	·277	·291	1·5	2·9	5·0	7·9	Ditto = **16·4.**

[ANALYTICAL TABLE—*continued.*]

Description - (I.). (II.).	Total solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Remarks.
Wells at Wellingboro' before softening (I.)	58·20	·036	·017	·004	0	·020	2·2	30·3	16·2	46·5	
(II.)	Fe_2O_3 and Al_2O_3		CaO	**MgO**	Na_2O	SO_3	N_2O_3	SiO_2	—	—	
	·35		21·97	**4·05**	2·31	11·30	0	1·01	—	—	
Ditto after softening with lime (I.)	26 30	·035	·014	·004	0	·017	2·2	1·1	14·9	16·0	
(II.)	·02		6·42	**2·16**	2·24	12·03	0	·63	—	—	
Well in chalk, Southampton, before softening (I.)	31·69	·024	·012	·005	·365	·381	1·6	23·0	2·7	25·7	
(II.)	·14		14·53	**·25**	1·21	·39	1·41	1·02	—	—	
Ditto after softening with lime (I.)	14·07	·021	·013	·004	·381	·397	1·6	5·6	3·0	8·6	
(II.)	·11		4·42	**·28**	1·12	·45	1·47	·94	—	—	Total **MgO** = ·92.
New River Company's water, London, before softening. (I.)	32·08	·150	·018	0	·308	·326	2·1	19·1	3·6	22·7	Total CaO = 12·35.
Ditto after softening with lime. (I.)	13·48	·103	·017	0	·329	·346	2·1	1·9	3·4	5·3	Total **MgO** = ·80. Total CaO = 2·14. Alkalinity (calculated as Na_2O) = 8·69.
Well in chalk below London clay, London (I.)	59·29	·036	·013	·010	0	·021	8·3	10·0	0	10·0	
(II.)	·20		3·20	**1·97**	24·85	11·41	0	1·25	—	—	
Well in chalk below London clay, Victoria Dock, London, before softening (I.)	58·76	·111	·017	·050	0	·058	16·7	19·8	8·0	27·8	
(II.)	·22		12·57	**2·82**	13·13	3·96	0	1·44	K_2O =	·93	
Ditto after softening with lime and caustic soda (I.)	44·20	·084	·016	·060	0	·065	17·3	2·4	6·0	8·4	
(II.)	·14		5·96	**·57**	15·76	4·01	0	·69	K_2O =	1·06	
Deep well in new red sandstone at St. Helens (I.)	56·40	·099	·029	·004	0	·032	3·6	29·4	11·8	41·2	
(II.)	·15		15·76	**6·31**	5·82	7·33	0	·97	K_2O =	·33	
Ditto after softening with lime (I.)	—	—	—	—	—	—	—	—	—	15·7	
(II.)	—	—	4·25	**5·41**	—	—	—	—	—	—	

It will be further seen that in all cases in which the proportion of magnesia is at all considerable (say, upwards of four parts), the permanent hardness is high (10 parts per 100,000 or upwards), whilst in none of the cases quoted is the permanent hardness above 10 without the magnesia being above four parts; in fact, in waters with low permanent hardness there is little chance of finding much magnesia, and *vice versâ*. Applying this rule, it will be found that in all probability an immense number of waters in common use must contain from four to six parts of magnesia per 100,000, a proportion which by some authorities is regarded as objectionable. Thus, of 28 samples of deep-well water from the new red sandstone analysed by the Rivers Pollution Commission, no less than 16 or more than 50 per cent. contained upwards of 10 parts of permanent hardness. Again, of 15 spring waters from the new red sandstone, seven exhibited upwards of 10 parts of permanent hardness. On the other hand, of 66 deep-well waters from the chalk, only five or 7·5 per cent. had upwards of 10 parts of permanent hardness; and of 28 spring waters from the chalk there was not one in which the permanent hardness amounted to 10 parts per 100,000.

If this investigation be extended to shallow wells, it will be found that the number of probably magnesian waters becomes enormously greater. Thus, of 87 samples of shallow-well water from the new red sandstone, no less than 84, or 96·5 per cent. had their permanent hardness in excess, and generally largely in excess, of 10 parts per 100,000; and again, of 33 samples of shallow-well water from the chalk, 27 exceeded the 10 parts of permanent hardness. Thus, without at all forcing the rule as to the relationship between permanent hardness and magnesia, it is obvious that waters containing from four to six parts of magnesia must be of very common occurrence indeed, and that a very large portion of our population must be supplied with them. Until, therefore, a far more searching inquiry than hitherto has been made into the alleged effect of such waters upon health, it appears to me highly undesirable that any importance should be attributed to such proportions of magnesia in drinking water which are otherwise of unimpeachable purity.

In conclusion, I would call attention to the effect of Clark's process on magnesian waters, which is recorded in several cases in the table. As a general rule, the proportion of magnesia removed by the treatment with lime is small, much smaller than that of the lime removed, but it is particularly worthy of notice that in the case where caustic soda was used in conjunction with lime, as is now frequently done in the softening of water for industrial purposes, the proportion of magnesia removed was greater than that of the lime.

As the recorded determinations of magnesia in British waters are comparatively scarce, I have thought it desirable to append the proportions of lime and magnesia in a series of 50 brewery-waters which I have examined from all parts of the country, although in only a few instances am I able to assign the precise source of the samples.

BREWERY WATERS.

PARTS PER 100,000.

———	Lime combined as Carbonate.	Total Lime.	Total Magnesia.
No. 1 - - - - -	11·96	18·21	·31
„ 2 - - -	7·49	7·74	3·90
„ 3 - - - - -	14·37	17·21	·20
„ 4 - - -	1·04	10·69	9·99
„ 5 - - - - -	13·91	20·67	·81
„ 6 - - -	3·36	6·26	2·24
„ 7 - - - - -	12·31	15·16	4·36
„ 8 - - -	3·24	6·34	1·34
„ 9 - - -	12·89	15·44	·76
„ 10 - - - - -	0	25·94	9·01
„ 11 - - -	16·27	20·46	1·81
„ 12 - - - - -	12·81	16·47	1·87
„ 13 (from Chapel-en-le-Frith, Derbyshire.)	0	1·04	·57
„ 14 (from Brighton) - -	14·06	20·87	1·11
„ 15 (Chalk below London clay)	2·81	2·81	1·33
„ 16 (from Cosham, Hants) -	17·41	23·46	2·84
„ 17 (from Brighton) - -	10·30	13·69	·41
„ 18 „ „ - -	11·51	16·39	·61
„ 19 (from Wrexham) - -	16·99	21·14	2·77
„ 20 - - - - -	6·40	10·74	·89
„ 21 - - -	10·37	10·69	6·21
„ 22 - - - - -	5·54	5·54	1·74
„ 23 - - -	9·53	11·13	·54
„ 24 - - - - -	13·11	15·67	·19
„ 25 - - -	2·84	3·37	1·40
„ 26 - - - - -	14·91	19·94	5·01
„ 27 - - -	5·91	7·16	1·07
„ 28 (from Reading) - -	15·90	25·57	1·21
„ 29 - - -	7·11	14·57	5·50
„ 30 - - - - -	20·26	23·04	8·81
„ 31 - - -	8·16	8·16	2·57
„ 32 - - - - -	14·51	17·00	7·36
„ 33 (from Cardiff) - -	5·04	14·86	3·91
„ 34 - - - - -	19·34	28·89	2·14
„ 35 (from Louth) - -	11·60	13·36	1·16
„ 36 (from Taunton) - -	9·79	10·16	1·27
„ 37 - - -	9·91	9·94	4·14
„ 38 - - - - -	9·36	11·87	·56
„ 39 - - -	13·94	15·21	·39
„ 40 - - - - -	·34	3·73	1·61
„ 41 - - -	17·64	32·56	5·99
„ 42 - - - - -	7·16	51·66	27·10
„ 43 - - -	12·71	46·60	20·57
„ 44 - - - - -	10·74	19·10	·60
„ 45 - - -	10·74	12·29	1·19
„ 46 (from Hertford) - -	12·61	14·37	·76
„ 47 - - -	·29	4·96	2·59
„ 48 - - - - -	10·04	11·00	3·03
„ 49 - - -	3·29	3·39	3·30
„ 50 (Chalk below London clay)	—	2·61	1·46

Average Magnesia = 3·41 parts per 100,000.

DISCUSSION.

Sir C. Cameron stated that the Dublin pipe-water was soft, containing only two grains of mineral matter per gallon. He found that soft lead pipes were sensibly affected by the water, and that small fish placed in tanks became affected or paralyzed. The waters in a large part of Ireland were hard waters, and contained magnesium as carbonate sulphate, and chloride. In many cases he had found from 3 to 10 grains of magnesium salts per gallon. The rock locally called calp, a limestone with large admixtures of aluminium silicates, silica, oxide of iron and iron pyrites, generally contained magnesia, often in large quantities. The Dublin well-waters were very rich in magnesium salts. He was not aware of any injurious influences upon health produced by these waters.

Dr. S. Barwise (Blackburn) stated that tinned lead pipes were quite satisfactory for soft peaty waters. The Blackburn water was very similar to the Dublin water; it acted on lead; but, owing to the Blackburn authority carefully insisting upon all lead pipes being lined with tin, they had no cases of lead poisoning.

Dr. T. M. Drown (Boston, U.S.A.) gave an account of the Massachussetts State Board of Health's investigations into the natural waters of the State, and described the establishment of isochlors or lines of equal chlorine-contents of the waters throughout the State.

Sir C. Cameron stated that in the soft waters in Ireland there was a relevancy between the amount of chlorine and pollution, but in the hard waters there was no such relevancy. Waters containing only 0·002 parts of albuminoid ammonia and 0·001 part of saline ammonia per 100,000 parts contained from 5 to 30 parts of chlorine per gallon.

The Importance of Periodic Analysis of the Air Breathed in Towns and Cities.

BY

K. N. Bahadhurji, M.D., Bombay.

Good food, good water, and good air are the three necessary elements which conduce to and preserve the health of living units. All sound and healthy sanitation for the preservation of public health is based on principles which vouchsafe and safeguard the purity and wholesomeness of the supply of these three vital elements. In the words of Dr. Guy: "Public Hygiene has to do with persons of every "rank of both sexes and of every age. It takes cognizance of the places "and houses in which they live, of their occupation and modes of life, "of the food they eat, the water they drink, and the air they breathe." Man is able for himself to reject any article of food which is injurious to his health, yet in all large towns and cities it is regarded as a canon of sanitation to provide against unwholesome articles of food getting into the general food-supply; and to do this effectually sanitation has called in the aid of legislation, and rightly so. The provision of a pure

water-supply in towns and cities is everywhere acknowledged as a great sanitary duty, and, after a pure water-supply is provided, to maintain it in a state of purity is regarded as a sanitary obligation. It is rigorously insisted, and justly so, that no impurity shall be permitted to have access to such water, because the fouling of drinking water is often followed by fatal diseases. All the consideration which sanitation bestows on the water of towns and cities is no less required for the town and city air. It will not be disputed that of the three important elements for the preservation of health and life air is the most important one, and naturally so, considering the power for evil it possesses when in a state of impurity. The mortality produced by using noxious articles of food is trivial as compared with the deaths from diseases due to the drinking of impure water; and the mortality on the score of drinking impure water is considerably less—at least ten times less—than the mortality due to the breathing of impure air. The infant requires no water, but pure air, and more of it than the adult, inasmuch as respiration is most active in infantile life. Zymotic diseases, which destroy so much infantile life, are due in a considerable measure to impurities in the atmosphere.

If, then, the air we breathe, compared with the water we drink, has such a powerful influence, and that to such an extraordinary extent, for good or for evil, on the health and life of the population according as it is pure or impure, the preserving of the purity of the atmosphere, and the *preventing* its fouling, even with the help of legislation, has certainly the strongest claims on the sanitary duties and obligations of civilized towns and cities. And we should, therefore, expect to find in all well-supervised towns that the condition of the air was as closely and constantly watched as the condition of the water. Instead of this, what do we find? Carefully prepared periodic chemical examinations of the water-supply are made, and the results are made public. The people know the quality of the water provided for them. From time to time the health officer on the strength of his analyses recommends special measures for purifying the water before use. But there is no such periodic examination made of the atmosphere, and not one person in 10,000 knows anything of the condition of the air he breathes. The municipalities provide, at considerable expense, a water-supply of as pure a quality as can be obtained, and they take measures to maintain its purity. A pure air-supply is a provision of nature, and nature does try to maintain its purity. As soon, however, as population increases and a large number of dwellings are put up within limited areas, as occurs in towns and cities, the atmosphere necessarily gets vitiated to a certain extent; and the conditions of town and city life are inseparable from a somewhat polluted atmosphere. The expired air of human beings and animals is one constant source of pollution of nature's pure air. The dry sewage or garbage of cities, which is always accumulating as fast as it is carted away, is another source of pollution, and the decomposition of liquid sewage, whether in drains, sewers, or cesspits, is a third source of pollution. All these sources of pollution of town and

city air are ever active, and more so by night than by day, more active in warm than in cold climates. The oxygenation in plant life and the perpetual motion of the atmosphere itself are the powerful means nature has at her command for preserving the purity of its air supply.

But are they enough to cope with the constant sources of pollution in towns and cities? Does not experience teach us that the efforts of man to vitiate the atmosphere are always, and especially in such places as towns and cities, able to overcome the efforts of nature to keep up the purity of her air-supply? It is an everyday experience that wherever large numbers of people are crowded together, in theatres, public halls, workshops, mills, and other similar places, and where the ventilation of the buildings is defective, the proportion of impure constituents increases, and the atmosphere becomes distinctly vitiated and unsuited to the preservation of health. This is the way in which the atmosphere of towns and cities is poisoned, and the tenants of these houses made ill. The deadly effects of atmospheric blood-poisoning were most unmistakably seen in the unfortunate victims of the Black Hole of Calcutta, and in the prisoners after the battle of Austerlitz. And the experiments of the late Dr. Angus Smith have familiarised sanitary officers with the effects of vitiated air in human dwellings and in public halls.

But experience has abundantly shown that the general atmosphere of towns and cities as observed in the streets, in open places, and in gardens is always in a more or less impure state. And indeed, certain towns and cities have such characteristic smelling atmospheres that their names could be pronounced by the sense of smell alone. The odours of Bombay are peculiar to itself, and travellers smell Bombay a long way off. But the inhabitants themselves get so used to their own town odours that they, in time, do not perceive them. The natives, although they daily indulge in ablutions before every meal to keep their persons clean—and cleanliness is health—little think of the pollution of the air they breathe, often a fatal pollution to which they undoubtedly contribute through indifference, or ignorance, or both. The degree of impurity in the air which is inseparable from the conditions of town and city life is easily exceeded, and whenever impurities in the atmosphere exceed ordinary limits rapidly and to an unusually high degree, their poisonous effects at once manifest themselves. Fevers and throat affections and cases of blood-poisoning multiply in the city, especially in the hot months, when the sewers are most active in polluting the house and town atmosphere; then it is, also, that zymotic diseases increase vastly and provoke a great mortality, all of which might be prevented if the atmospheric conditions of the towns were regularly investigated, for means might be taken before the impurities have gained access to the atmosphere to such a dangerous extent. These rapidly occurring and often fatal effects of the fouling of the town and city air, no doubt, arrest attention, for they cause sudden and striking rises in the mortality. But there is a more insidious and slow process of poisoning which the population at large undergoes, and the

extent of its deadly influence is far in excess of that of the rapid process. A plentiful supply of fresh and wholesome air is the chief food of the blood. A falling off in its food-supply either in quality or quantity, or in both, is necessarily followed by poverty of blood which ends in general deterioration of physique. Not only does the blood suffer thus, but so also do the lungs, through which the air has access to the blood. When a healthy plant from the open garden is removed to a dark and dingy place with a foul atmosphere, the freshness and colour of its leaves—the lungs by which the plant breathes—decline, and signs of fading life gradually appear which ultimately overtake the whole plant itself. Is it to be wondered at that in the reaction between human lungs and the atmosphere impure air exercises similar deleterious effects? Tuberculosis derives its chief power from foul air. But short of true tubercular disease, there is a low form of lung breaking-down, a mild form of chronic phthisis which one meets with extensively in practice. Evidences of this form of lung mischief are to be found in patients who are admitted into the hospitals for other complaints. They are to be very generally noticed amongst people who have no idea of ventilation or of the wholesomeness or otherwise of the air they breathe, such as the occupants of chawl-rooms (which may have no windows, or, if there be any, they are generally shut); amongst people whose dwellings are apparently like mansions, but who occupy rooms therein to which one cannot see his way without candle-light even at mid-day; and in the occupants of lofty dwellings which have their atmosphere constantly fouled by the emanations from the godowns and animal-sheds below, and by the foul gas escaping from the decomposing garbage in the gullies, or by the sewer gas which keeps up a constant current through holes and escapes in the sullage pipes specially provided for it by the genius of the plumber. Indeed, the plumber has more to answer for in endangering public health and life than the jerry builder who jeopardises the lives of a few individuals by his fragile structures. The incompetent plumber is certainly the arch offender. He undermines general public health, and that in an insidious and unwary manner. It is a matter of congratulation that a special meeting of the Congress has resolved to urge upon the authorities the necessity of registration of plumbers, thereby eliminating the most serious, and yet the most preventible, element of danger to public health, by legally exacting from them a standard of education and training which would naturally carry with it a knowledge of the responsibility of their vocation and of their duty to the public at large. These little details have been gone into only to show the extent and gravity of the danger to public health from the undue fouling of town and city air, and all from preventible causes. Great and grave as the mischief is that is wrought by this fouling of Nature's pure air, the remedy is most simple and by no means difficult to apply, and to apply successfully. But to apply the remedy successfully, the right character and source of pollution must be traced; and neither the character nor the source of pollution can be traced unless systematic tests are applied regularly. And this cannot be done unless systematic air analyses are regularly and periodically made.

It will now be apparent that a regular examination of the air in towns and cities is as necessary, for the purposes of preserving public health, as the examination of the water-supply; and, indeed, more necessary. It is strange that no regular system of examination of the air of towns and cities has as yet found a place in sanitary police. Air analysis is undertaken in individual cases here and there for certain purposes. But the object of this paper is to point out that the work should be undertaken systematically in all towns and cities; and that the examination should include the air condition, not only of public halls, workshops, and kindred places, but of private dwellings, gulleys between houses, lanes, streets, parks, playgrounds, and places of all kinds temporarily or permanently occupied by human beings and animals. Much sanitary advantage would result if air analysis as now discussed were given its regular place in the reports of the health officer. It may be mentioned that, by resorting to air analysis, the atmospheric conditions of the public hospitals of Great Britain have been permanently improved. Exactly the same amount of improvement could be effected in towns and cities by applying similar tests to the whole of the populated areas. Fortunately, it happens that the sanitary duty now insisted on may be carried out without involving any but a small financial expenditure, while the chemical qualifications required to do the work are by no means great. In Indian towns and cities the subject of air analysis is almost unknown. In Bombay the health officer is the water analyst, but an air analyst has no existence. It is in India that this system would prove a very decided blessing, and for two special reasons, (1) because it is there that organic and vegetable pollution largely prevails, and decomposition of impurities takes place with great rapidity in the face of a high temperature, (2) because liquid sewage is a dangerous difficulty in that country, much more dangerous than in England.

DISCUSSION.

Professor Odling stated that the analysis of air for sanitary purposes was not new, and pointed out its value in regard to the incidence of disease. He considered that such an investigation as that proposed by the author to be carried out in India would be most important.

Sir C. Cameron said that the biological examination of air was of even more importance than the chemical. As a member of the Army Sanitary Committee, and a Special Commissioner from the War Office, he investigated the causes of the excessive amount of typhus fever in the Royal Barracks, Dublin. He found that the number of micro-organisms falling per minute per square foot in a well-known unhealthy part of the barracks greatly exceeded the number falling in healthy parts. As to the frequency of pulmonary disease in Bombay, where there was a high temperature and constancy of temperature, he believed that changes of temperature or exposure to cold produced bronchitis, post-nasal catarrh, &c., but did not affect the lungs; these, however, became the seat of

disease when tainted air was inspired. The prevalence of pulmonary disease in Bombay appeared to be due to blood poisoning.

Dr. Gibbon insisted on the importance of the systematic chemical and bacteriological examination of air in all cities and towns.

Dr. Nasmyth had investigated the air of mines, and his experience was that the air of coal mines was much purer than the air of an ordinary inhabited house. He pointed out that the organic impurity of any given atmosphere could not be measured by the number of organisms that it contained, the number of these organisms depending upon other conditions. Near habitations the number of micro-organisms increased largely in the air. He regarded it as very important that the air of mines should be subjected to systematic examination.

On the Effects of the Respiration of Carbonic Acid on Man.

BY

W. Marcet, M.D., F.R.S.

The subject is dealt with under three headings:—

Firstly. The source of the presence and accumulation of carbonic acid in the air breathed.

Secondly. The action of re-breathed air on the human body.

Thirdly. The action of carbonic acid gas breathed in volumes which either produce insensibility or prove fatal.

Firstly. The source of the presence and accumulation of carbonic acid in the air breathed.

This is derived principally from the decomposition of organic matter in the earth, and also in some measure from the consumption of coal. The amount of coal consumed in London and 15 miles around is about 9,400,000 tons per annum, which would give out 28,866,867 tons of carbonic acid, equal to 3·53 cubic miles of that gas. A source of carbonic acid, perhaps least thought of, is derived from the process of fermentation, as in the manufacture of beer; this gas is usually lost, but it is now, in some instances, collected from the vats, condensed into the liquid form, and used mostly for refrigerating purposes. The amount obtained from Messrs. Guinness and Co. is said to reach the enormous figure of 32 tons per diem. Again, the inhabitants of large towns must contaminate the air with their breath. The occurrence of any great excess of carbonic acid in the atmosphere is prevented, however, by the extreme diffusibility of this gas, so much so, that under a comparatively clear sky in the streets of a large town like London, there are barely more than four parts in 10,000 of air, while in the country the proportion may be considered to be between 3·5 and 3·8 parts.

I have made experiments relating to this subject in conjunction with my friend Mr. Landriset, D.Sc., of Geneva. They have been

recorded in the "Archives des Sc. Nat. of Geneva," and subsequently in the "Journal of the Meteorological Society for 1887." Our object was to find out if the proportion of atmospheric carbonic acid varied between such different levels as the town of Geneva and the highest point of the Jura Mountains, called the Dole, the difference in altitude being 4,193 feet. Former experiments on this subject by Th. de Saussure and P. Trochut had given different results; de Saussure found an increase of CO_2 in higher altitudes and Trochut a decrease. Our experiments were undertaken simultaneously at both stations, and the state of the weather was carefully recorded at the time, a precaution the other observers do not appear to have taken. Fifty analyses were made altogether, by Pettenkofer's method, at both stations inclusively, and the results show distinctly that in fine, clear weather, there was no difference between the proportions of CO_2 in the air of the two stations; therefore, under a cloudless sky, the carbonic acid diffuses equally throughout the atmosphere. Three experiments made on the mountain while the observer was in a fog or cloud, the corresponding experiments near Geneva being carried out in fine weather, gave 3·24 parts of CO_2 for the high station, and 3·88 for the low station and in clear weather; on another occasion, one experiment on the mountain while in the clouds gave 2·94 of CO_2, while three-quarters of an hour afterwards, the fog having temporarily disappeared, the sun came out brightly and the CO_2 rose to 3·91 parts, falling again when the cloud formed afresh round the observer. It follows, therefore, that on the top of a mountain there is less CO_2 in a cloud or fog than in fine clear weather.

From Dr. Russell's experiments, and those I have also made on the same subject, there can be no doubt that the very reverse takes place in large towns in foggy weather; when the streets of London are obscured by a dense autumnal fog the atmospheric CO_2 is greatly increased. This is clearly due to the carbonic acid generated in towns being absorbed by fogs, while the diffusion of the gas is much less rapid through fog than through the atmosphere when clear. But on the top of a mountain the CO_2 formed on the spot is small, and when, after diffusing through a cloud, it reaches the outside, the tension of the gas is rapidly increased by the sun's action, and it escapes. This same tension will prevent the cloud from absorbing CO_2 from below, and so the cloud loses its atmospheric CO_2.

Secondly. The action of re-breathed air on the human body.

According to E. A. Parkes, the effect of fœtid air containing organic matter produced by respiration is very marked on many people, causing heaviness, headache, and in some cases nausea. It is stated, in this author's "Manual of Practical Hygiene," p. 115, that from experiments on animals, Gavarret and Hammond have found that the organic matter of the breath is highly poisonous. Besides CO_2, we have certain volatile constituents of food, such as alcohol, garlic, &c., which are found in expired air after being swallowed. Like all other substances ejected from the body, such gaseous products must be unfit for use, and injurious in a concentrated form, but it is also very possible that

some nitrogenised organic matter, not present in food in a volatile form, is given out from the lungs. Expired air invariably discolours potassium permanganate, gives rise to the formation of sulphurous acid when passed through sulphuric acid after filtering through cotton wool, and can be made to yield ammonia. As to the unhealthy action of ill-ventilated dwellings, an interesting paper in the "Phil. Trans." for 1887, by Messrs. Carnelley, Haldane, and Anderson, shows that there is a great increase in the mortality of children, especially under five, who inhabit one-roomed houses over those in four-roomed houses, and that this is owing to the accumulation in the air of carbonic acid, micro-organisms, and other atmospheric impurities.

I have lately carried out experiments on re-breathing air, which are described in the "Proceedings of the Royal Society" for the present year. The experiments were made on four different persons in a state of repose, the mode of breathing being perfectly natural. They began by expiring the air they breathed into counterpoised bell-jars suspended over salt water, and the CO_2 this air contained was determined; the next, or second stage, of the experiment was to re-breathe 35 litres of air from and into a counterpoised bell-jar during five minutes (inspiring through the nose and expiring through the mouth); immediately after emitting the last expiration of re-breathed air, and while taking an inspiration of fresh air, the air expired was turned into another jar by means of a three-way cock. After the third quantity of air had been collected, the air expired was directed into the first jar (now emptied) and the fourth and final quantity was taken. The carbonic acid in every case was determined by Pettenkofer's method.

The results from this inquiry were as follows:—

(1.) On re-breathing air in a closed vessel less carbonic acid is expired in a given time than in ordinary breathing.

(2.) The persons who emit most carbonic acid in re-breathed air are those who expire most carbonic acid and air in the same time in ordinary breathing.

(3.) On re-breathing 35 litres of air in a closed vessel for a period of five minutes, the volume of this air undergoes a slight reduction.

(4.) When fresh air is taken into the lungs, immediately after re-breathing air in a closed vessel, the volumes of air re-breathed and weights of CO_2 expired are greater than in ordinary breathing.

(5.) The effects produced on the chemical phenomena of respiration by re-breathing 35 litres of air in a closed vessel during five minutes have passed away in less than six minutes after the breathing of fresh air has been resumed.

In an experiment, made before the Physiological Society, the gentleman who assisted me at that time re-breathed for nine minutes the small volume of 10 litres of air; a recording instrument being connected with the bell-jar showed distinctly the increase in the amplitude of the

respirations and in the speed of the respiratory movements as the air became more and more vitiated.

My inquiry yields one result, which appears to me important in point of view of hygiene—that the effects produced by re-breathing air, I mean the increased volume of air breathed in a given time and CO_2 expired, pass off very rapidly after breathing pure air. Hence, the importance for people who are called upon to make a prolonged stay in ill-ventilated apartments to go out into the open air as often as possible, were it only for a few moments at a time, and to sleep in well ventilated rooms.

Thirdly. The action of carbonic acid gas breathed in volumes which either produce insensibility or prove fatal.

The effects produced by the respiration of air mixed with carbonic acid vary considerably according to the rapidity of the action. The influence due to the suddenness of the exposure, is well illustrated by an experiment of Claude Bernard. A sparrow was placed under a glass receiver of two litres' capacity; after two hours, it was still alive, two other birds were then introduced into the receiver and they died; the first sparrow was withdrawn an hour later, warmed and when quite well, was again introduced, when it died immediately. This experiment is very interesting in point of view of hygiene, showing that people who become gradually accustomed to a close atmosphere can exist in comparative comfort under conditions which might prove baneful, and perhaps fatal, to others used to a life in the open air.

Claude Bernard also found that carbonic acid is innocuous when injected into the veins and arteries of a dog, the gas being exhaled at the lungs; on the other hand, birds died in air containing in 100 parts:—

Oxygen - - - -	39
Carbonic acid - -	13
Nitrogen - - - -	48
	100

showing that when breathed, even in the presence of an excess of oxygen, the action of CO_2 is no longer the same as when injected; the injected gas is being continuously given out at the lungs, the inspired gas undergoes continuous accumulation until its proportion is too great for the maintenance of life.

I have made experiments upon myself and others, when about 35 litres of air containing from 2·5 to 4 per cent. of pure CO_2 was inspired from a bell-jar and expired into the external air. The CO_2 accumulating in the body, the effects became more marked as time elapsed; the first minute a slight want of air was experienced, but in the fourth or fifth minute, the sensation was decidedly uncomfortable, and could not have been endured much longer.

Dr. Angus Smith made investigations (published in 1872, in his book on "Air and Rain") in which an air-tight chamber containing 3·84 per cent of CO_2 was entered by two gentlemen, who got headaches

instantaneously and were unable to stay above seven or eight minutes. Dr. Smith remained in the chamber for 20 minutes, and then felt very uncomfortable, and anxious to get out. An interesting inquiry by Dr. Emmerich was made at Munich in 1887 or 1888, and published with an addendum by Dr. von Pettenkofer. Several observers, including Dr. von Pettenkofer, having entered a vault in the Institute of Hygiene at Munich in which several candles were burning, CO_2 was evolved by opening two cylinders containing the compound in the liquid form; in about a quarter of an hour two of the candles went out and several persons left the vault, only Dr. von Pettenkofer, Herr Trillich, and Herr Rats remaining, the two latter gentlemen staying until all the CO_2 in the cylinders had evaporated. The candles went out when the air contained eight per cent. of CO_2. According to other experiments by Karl Friedlander and Edwin Herter, rabbits can live over an hour in an atmosphere containing 34 per cent. of CO_2.

There are many records of accidents from the inhalation of carbonic acid gas: one of the most remarkable I ever came across is recorded in a Geneva newspaper, the "Journal de Genève," of the 7th October 1886. The account is very short, and I venture to give a verbatim translation of it. "A melancholy accident has just " thrown into a state of utter consternation the small village of " Constet, near Barsac, 30 kilometres from Bordeaux. Two labourers, " named Loubrié and Blanc, were working in a cellar belonging to " Mr. Gaussem, a merchant. Blanc observed that wine was fermenting " in a vat; he went into it with the object of pushing down the grapes, " which the evolution of gas in the fluid had driven to the surface. He " instantly fell asphyxiated. Loubrié called for help, and a man named " Finore, who was working in the neighbourhood, ran up and went " into the vat to try and save Blanc. As he did not re-appear, Loubrié " tried to rescue both men but he also perished in a like manner.

"Two courageous persons, Chassin and Puzos, went down one " after the other into the vat, notwithstanding the protests and suppli- " cations of the witnesses of this horrible drama; both of these men " met with the same fate as the others. In order to remove the dead " bodies a portion of the roof over the vat had to be demolished. " Finore alone was still breathing and there are some hopes of his " recovery."

The foregoing remarks show:—

1st. That when air containing an excess of CO_2 is breathed, the gas accumulates rapidly in the blood, and under such a condition the phenomena of nutrition are more or less interfered with; and also that people working in ill-ventilated rooms and buildings, should, for the preservation of their health, sleep in as pure an atmosphere as possible, where they will rid their blood of the carbonic acid absorbed in the day time.

2nd. That the effects produced by the inhalation of carbonic acid gas depend greatly on the rapidity of the exposure. The sudden inhalation of air containing a large proportion of

the gas may produce rapid insensibility and death; while this same air might have been breathed for some time with a certain degree of impunity, had the carbonic acid present been introduced gradually.

3rd. That when life is threatened by the inhalation of carbonic acid, there is no reason to despair of artificial respiration so long as the heart is beating; the gas will diffuse rapidly from the blood into the air with which the lungs are inflated, and will thus, be carried out of the body.

DISCUSSION.

Sir Chas. Cameron drew attention to the experiments of Dr. Hammond in the United States, 10 or 12 years ago, showing that the harmful nature of expired air was due, not to the carbonic acid, but to the organic impurities it likewise contained, and that the ill effects continued after the removal of the carbonic acid by chemical means. This is also shown by the health of those employed in mineral water manufactories.

Professor Odling pointed out that the effect of the inhalation of pure carbonic acid gas was very similar to that produced by nitrous oxide.

Friday, 14th August, 1891.

The President, Sir H. ROSCOE, in the Chair.

Meteorology in relation to Hygiene.

BY

Alexander Buchan, M.A., LL.D., F.R.S.E.

No city can be compared with London as affording the best available materials for an inquiry into the relation of weather and health: the data for the inquiry being supplied (1) from an enormous population spread over an area so restricted that it may be regarded as having one uniform climate during each of the seasons of the year; (2) by fairly satisfactorily full reports, week by week, of weather and of the number of deaths from the different diseases; and (3) by returns extending over a sufficiently long time, viz., 46 years.

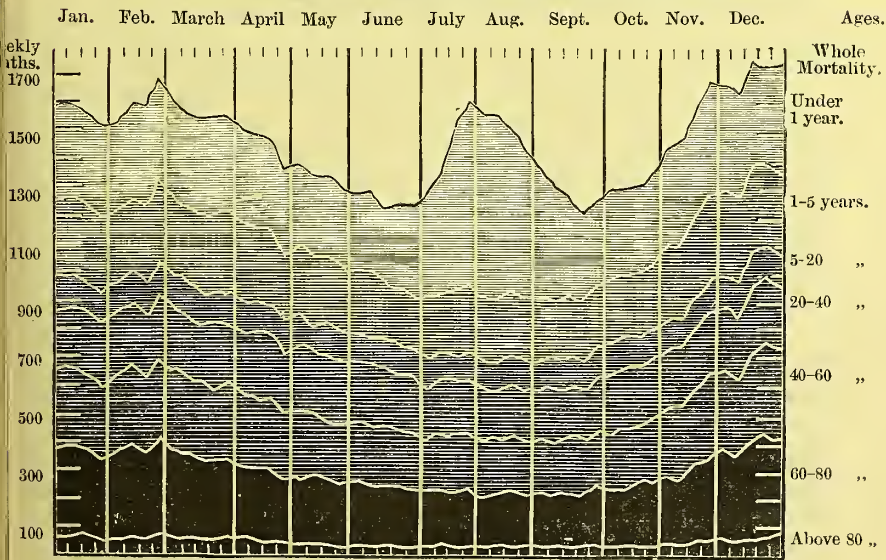
As regards such diseases as diarrhœa, bronchitis, and heart disease (Figs. 3, 2, and 6), which are to a large extent directly and immediately under the influence of temperature and humidity; and such epidemics as scarlet fever, diphtheria, and whooping cough (Figs. 4, 5, and 10), the rate of mortality from which is very largely determined by season and weather; a comparatively small number of years is required to give a satisfactory approximation of their true weekly curves or mortality. But in dealing with the data of a large number of diseases whose mortality is relatively small, it soon becomes apparent that all the 46 years are needed in order to give sufficiently close constants for the curves of weekly mortality for a considerable number of these diseases. The curves of weekly mortality thus arrived at suggest complications of special diseases and their connexion with each other, which complications would be entirely masked if monthly averages alone were employed.

The climate of London in its relations to the public health may be divided into six different types according to the season of the year, viz.:—1. *Damp and cold*, fourth week of October to third week of December; 2. *Cold*, fourth week of December to third week of February; 3. *Dry and cold*, fourth week of February to second week of April; 4. *Dry and warm*, third week of April to third week of June; 5. *Heat*, fourth week of June to 1st week of September; 6. *Damp and warm*, second week of September to third week of October.

The curve for the whole mortality (Fig. 1) shows two maxima of very different degrees of intensity; one the greatest and longest-continued

Fig. 1.

Mortality at different Ages—for both Sexes and all Causes.

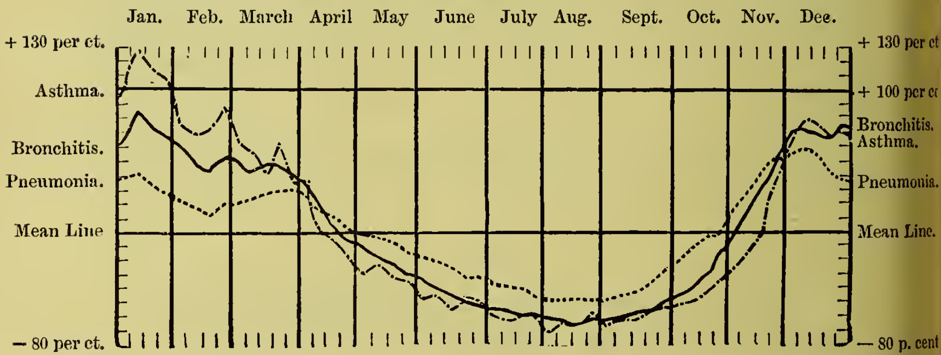


extending from November to April, and the other strictly confined to the summer months. Now the singular point of the summer maximum is that it virtually disappears if the mortality among infants under one year be subtracted from the whole mortality. Hence the most deleterious element in the climate of London to the health of the people is the low temperature of the winter months; and this remark may be extended *to all* climates in which the temperature of the winter months falls repeatedly below 40°.

Of the diseases by which the excessive winter mortality of London is occasioned, the first place must be assigned to diseases of the respiratory organs (Fig. 2), notably bronchitis and pneumonia, to which alone one-fifth of the whole mortality of London is attributable. Statistics show that the greatest fatality from these diseases occurs when the temperature is between 32° and 40°; or, say, between the temperature of the maximum density point of water and its freezing point. Thus, in New York, where the mean temperature of winter is 10° lower than

Fig. 2.

Bronchitis, Pneumonia, and Asthma—for all Ages and both Sexes.



that of London, the mortality from bronchitis and pneumonia is greatly less; and it is also greatly less in Melbourne, where the winter temperature is 10° higher than that of London. Indeed, in Melbourne the death-rate from diseases of the respiratory organs forms but a small fraction of the whole deaths of the year. This general result is confirmed by the climatic and mortality returns of other cities. Similarly, the higher summer temperature of New York as compared with London results in a higher death-rate in New York in spring and early summer from brain diseases (Figs. 7 and 8).

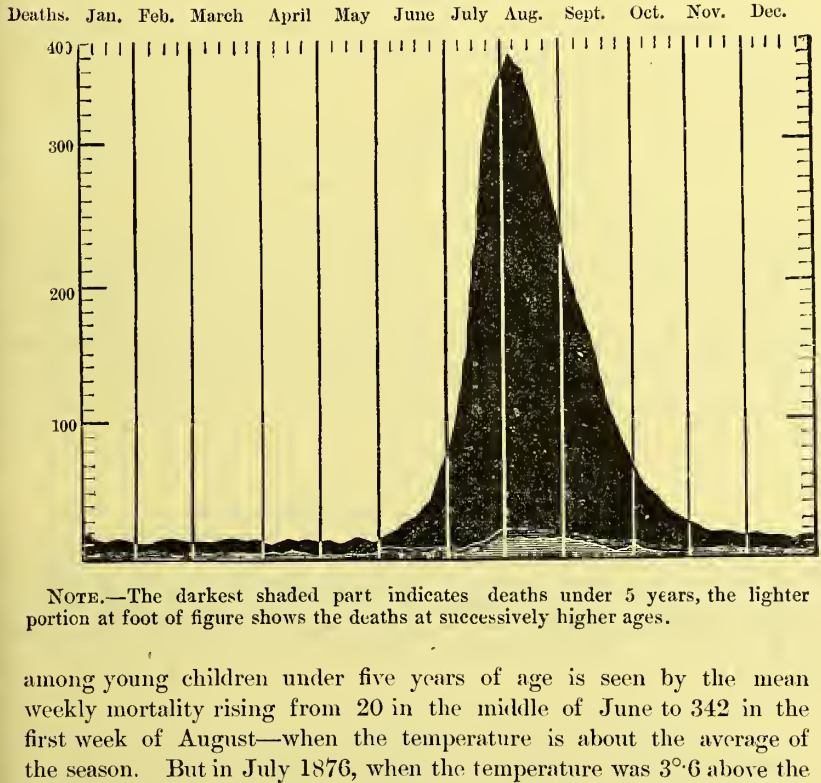
There is, however, an element of weather other than mere temperature which plays an important part in bringing about a high death-rate. That element is fog, which in proportion to its density and persistency sends up the mortality with alarming suddenness to a degree exceeded only by Asiatic cholera. Let me emphasize the fact in the strongest manner that it is not low temperature by itself, but low temperature along with dense and persistent fogs which is accompanied with this appalling mortality. A single illustration will make this clear.

Last winter was, as regards London, one of the very coldest on record. With the low temperature the deaths from bronchitis rose greatly above the average of the season, the highest in any single week being 711 during the second week of the year. But during the low temperature and dense fogs of the winter of 1880 the mortality from bronchitis rose to 1,223 during the first week of February.

In summer, when '*heat*' is the chief characteristic of the climate, the maximum at that season is caused by diseases of the abdominal organs (Fig. 3). The peculiarly malignant character of summer diarrhœa

Fig. 3.

Diarrhœa.



NOTE.—The darkest shaded part indicates deaths under 5 years, the lighter portion at foot of figure shows the deaths at successively higher ages.

among young children under five years of age is seen by the mean weekly mortality rising from 20 in the middle of June to 342 in the first week of August—when the temperature is about the average of the season. But in July 1876, when the temperature was 3°·6 above the average, the mortality from diarrhœa among children rose to 502 on the last week of that month. On the other hand, during the cold summer of 1860 the largest number for any week did not exceed 90.

Of the large British towns, the lowest mortality from summer diarrhœa is that of Aberdeen, which has at the same time the lowest summer temperature. The diarrhœa mortality of each large town rises from year to year proportionately with the increase of temperature; but the rate of increase differs widely in different towns, pointing to causes other than mere weather, these causes having their origin in the sanitary condition of the town. The recognition of this in quite recent

years, and the measures taken to remedy matters, are among the most satisfactory outcomes of the inquiries we have now in hand.

The curves suggest several contrasts and other relations *inter se.* Thus, while the whole mortality shows September and October to be two of the healthiest months of the year, the curves for scarlet fever (Fig. 4), typhoid, and diphtheria (Fig. 5) form striking exceptions. These three curves are closely related to each other, each having, however, a well-marked individuality of its own. It is a singular circumstance that diphtheria shows closer relation in the phases of its death-rate with typhoid than with scarlet fever. The curve for mortification is substantially that of nervous diseases, and the curves for erysipelas and puerperal fever are in all essential respects the same. The curve for old age runs exactly parallel with the curve for paralysis. The curves for skin diseases, rheumatism, dropsy, pericarditis, Bright's disease, and kidney disease exhibit the closest and most striking alliances with each other.

Fig. 4.

Scarlet Fever—for all Ages and both Sexes.

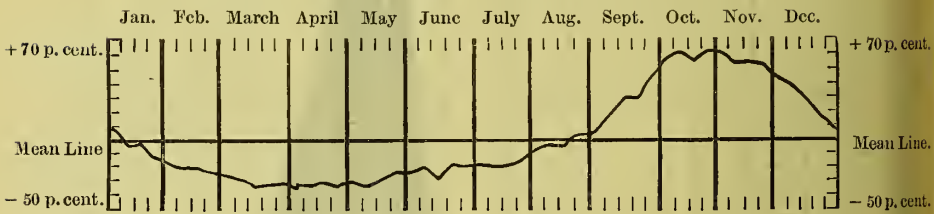
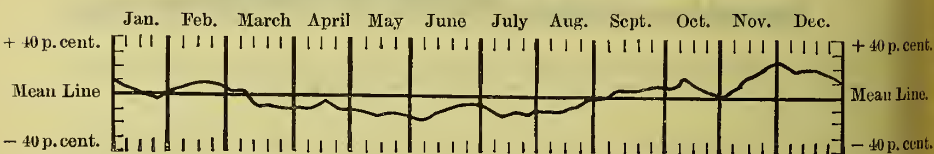


Fig. 5.

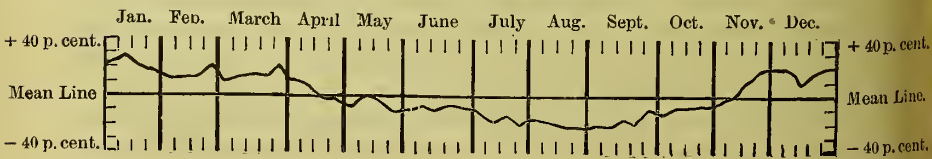
Diphtheria—for all Ages and both Sexes.



Lastly, while diseases of the abdominal organs attain their greatest mortality when temperature is highest, diseases of the respiratory organs and of the circulatory system (Fig. 6) when temperature is lowest,

Fig. 6.

Circulatory System—for all Ages and both Sexes.



nervous diseases (Figs. 7 and 8), phthisis (Fig. 9), and whooping-

Fig. 7 (New York).

Meningitis and Encephalitis—for all Ages and both Sexes.

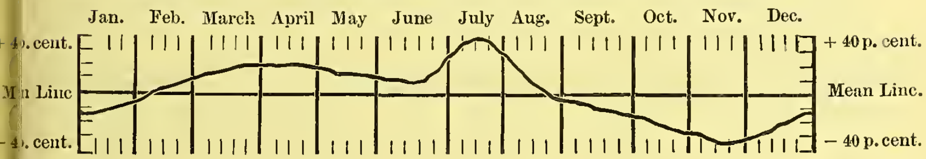
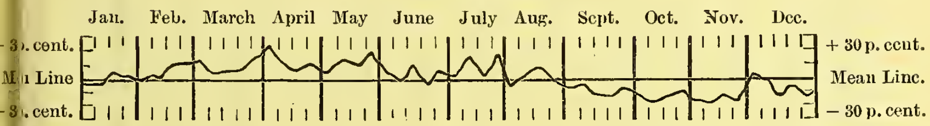


Fig. 8 (London).

Cephalitis.



cough (Fig. 10) in the dry weather of spring and early summer, and skin diseases and certain fevers during the raw weather of autumn and early winter, the diseases which are quite removed from weather influenees (such as peritonitis) exhibit curves which show no obedience to season, but merely a succession of sharp irregular serratures.

Fig. 9.

Phthisis—for all Ages and both Sexes.

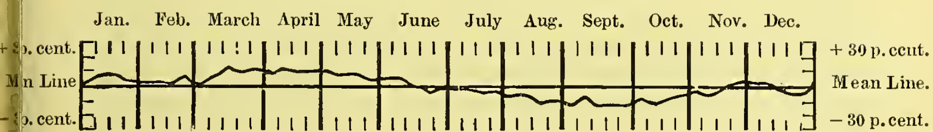
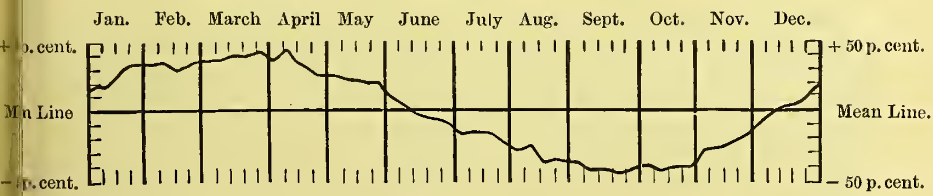


Fig. 10.

Whooping Cough—for all Ages and both Sexes.

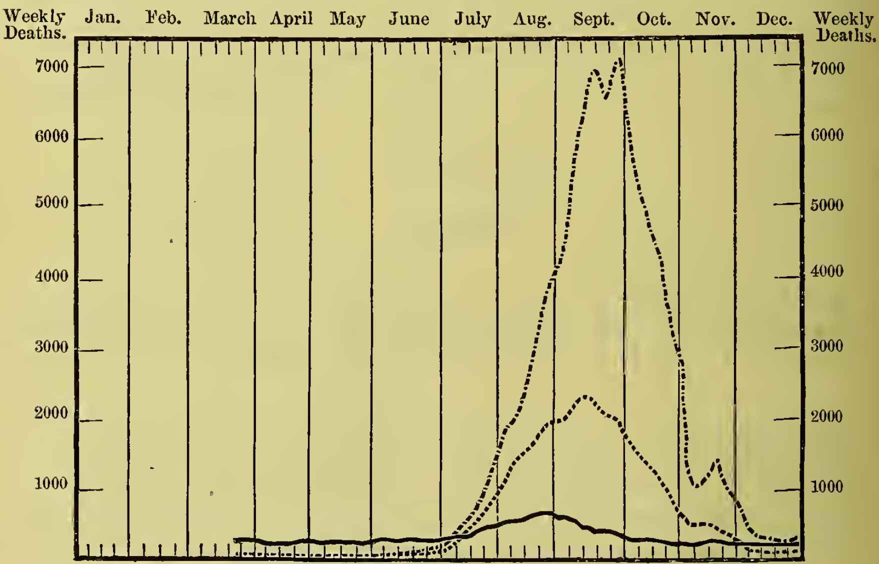


The weekly returns of the last six plagues of London (Fig.11), published in 1662 by John Graunt under the auspices of the Royal Society, have been examined in view of the results now established. The manner in which

the Plague, as a death-producer, obeyed the weather, is striking. It did so exactly as we now see bowel complaints to be influenced by weather.

Fig. 11.

Showing by Three Curves—(1) Doubly-dotted Line or Highest Curve, Weekly Mortality during the Great Plague in 1665; (2) Lower Dotted Curve, Mean Weekly Mortality of the Six Plagues; and (3) Solid-lined Curve, Mean Weekly Mortality from all other Diseases during continuance of the Six Plagues.



The curve for the Plague bears no resemblance whatever to the curve for typhus, or indeed to that of any disease except bowel complaints. This close resemblance suggests whether there was not a closer alliance between them than has been suspected. If the results now ascertained be regarded as a fair outcome of our inquiries into the relations of weather and health, it is plain that such investigations may point to a set of morbid processes which have been cloaked by prominent phenomena, apparently of a primary, but in reality of a secondary character.

DISCUSSION.

Dr. G. B. Longstaff stated that meteorological curves and curves of deaths, however closely related on cause and effect, could not possibly correspond exactly, owing to the fact that the interval between the death and its registration averaged about five days, and the interval between the commencement of an illness and a resultant death was of uncertain and often considerable duration. He stated that, in his opinion, meteorological changes were not of themselves the cause of death, though the number of deaths appeared to be a function of those changes. Fog alone, or cold alone, did not directly cause the deaths from respiratory diseases; but there was a *tertium quid*, perhaps the germ of ordinary communicable catarrh. Fogs must be distinguished into

those mixed with smoke and those free from smoke, the latter probably not having any pathological significance. Again, smoke fogs must be divided into those in contact with the ground and those forming a pall overhead, probably the latter would be found to have comparatively small influence upon the mortality. He explained the very close relation between the curves of apoplexy and mortification by the fact that both are symptoms of disease of the arteries chiefly in old people; that cold raised the blood pressure and hampered the circulation, resulting in some cases in rupture of an artery and apoplexy, in other cases in stopping of the local circulation and mortification. In conclusion, he stated that Messrs. Buchan and Mitchell deserved great credit for their valuable improvements in the methods of exhibiting statistical results.

Dr. Tripe, Medical Officer of Health, Hackney, said that Dr. Longstaff had already referred to the interval which elapsed between the death and registration, and also to that between the weather causing the illness and the deaths. He had in his investigations allowed two weeks, but he now thought that to be too small an interval except as regards diarrhœa and perhaps diphtheria. In the former, the action of heat is rapid so soon as the temperature of the soil at a depth of six inches, or of the Thames, reaches 65°. As to the effect of fogs, they vary very much according to their density and quality. This was well shown by the fogs during January and February 1880, when they were so dense as to prevent him from seeing the kerb, and the number of deaths from inflammatory diseases of the lungs was then more than double those in 1891, when the temperature was lower than in 1880.

Mr. W. North called attention to the curves drawn by Professor Tacchini, showing the relation between the rainfall in the months of March, April, and May, and the number of cases of fever in the Province of Rome in the autumn. As the result of his own experience in the Roman Campagna, the author was led to entertain grave doubts as to the possibility of explaining the phenomena of intermittent fever on the hypothesis of a pathogenic organism; the relation of malaria to local climatic conditions is no longer a matter of question, and is so close that it appears to be not unreasonable to regard the latter as powerful factors in causing, if they are not themselves the cause of, the disease. It appears that the mode of operation of these climatic changes on the organism may be accounted for on some such hypothesis as the following: the temperature of the body may be reasonably regarded as the result of the interaction of two rhythmically acting forces, interference with one or other of which will produce the phenomena of beats, to which the regular intermission of malarial fevers have at least a very close resemblance.

Dr. Russell pointed out, with regard to London fogs, that when there was a great increase of death-rate a low temperature always accompanied the fog, but that there were, on the other hand, several cases of dense fogs without decrease of temperature, and then the death-rate did not fall below the average; hence it appeared unfair to say that the fog itself was the sole cause of the great mortality.

In reply to Dr. Russell, **Dr. Buchan** stated that he fully agreed that it was impossible to determine how far the increased mortality in cold foggy weather was due to the fog, and how much to the low temperature; but he wished to emphasise the fact that it was the combination of the two which was so very fatal.

Influenza and the Weather of London.

BY

Sir ARTHUR MITCHELL, K.C.B., and Dr. BUCHAN.

This subject was investigated by us in the spring of 1890, and the results were published in the Journal of the Scottish Meteorological Society. In that paper are summarised the statistical facts relating to weather and influenza up to that date, extending from 1845 to 1890. These have been published in the weekly reports of the Registrar-General. Of the results then arrived at (that is, previous to the last epidemic), the following is a brief summary :—

It was found that the distribution of temperature and the distribution of deaths from influenza during the weeks of the year were inversely related; that when the mean temperature is low, the mean death-rate from influenza is high ; and when temperature is high, the number of deaths from influenza is low. Further, the distribution of deaths from influenza is essentially the same distribution as that for bronchitis and pneumonia, or, speaking generally, for diseases of the respiratory organs.

Since registration of deaths commenced in London, deaths from diseases of the respiratory organs (*vide* Fig. 2)* have been shown to be most numerous during the winter months of the year; and, with some marked differences, there is substantial agreement in the annual distribution of deaths from the different diseases of the respiratory organs. During exceptionally severe winters and during dense fogs there is an exceptionally high mortality from bronchitis and pneumonia; and an enormous increase in the death-rate from these diseases during extremely cold weather and densely foggy weather has been an unvarying and apparently an inevitable consequence.

Similarly, deaths from heart disease (*vide* Fig. 6), including the other diseases of the circulatory system, and deaths from phthisis (*vide* Fig. 9), reach their annual maximum fatalness when the mean annual temperature is absolutely lowest, and when the east winds of early spring acquire their greatest frequency and malignancy respectively; and when it happens in any year that these features of the weather are more pronounced than usual, so is the excess of the mortality from these diseases also more pronounced.

Now when the death-rate from diseases of the respiratory organs, of the circulatory system, brain diseases (*vide* Figs. 7 and 8), or phthisis have strikingly exceeded the per-centages due to the temperature and fogs prevailing at the time, it has been found that something of an exceptional character has been in operation at the same time; and that

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* The figures referred to are those contained in the preceding paper on *Meteorology in relation to Hygiene*, p. 98, *ante*.

something apparently lowering the public health has been the prevalence of influenza in a more or less epidemic form. At these times, it was noted that the diseases which were abnormally increased were, broadly speaking, just those diseases which annually go to swell the death-rate at the times of the year when influenza happened to be clearly epidemic. In other words, these were the diseases with which occurred the more serious complications with influenza.

It is remarkable that though during these 46 years the deaths from influenza were virtually restricted to the cold half of the year, yet when the epidemic set in, the degree of fatalness has been wholly uninfluenced by the changes of temperature, sometimes strikingly large and sudden, that occurred during the weeks when the mortality from influenza was great.

The last epidemic of influenza in London may be considered as having commenced about the middle of April 1891; the deaths in the third week of that month were 10, after which they rose with alarming suddenness week by week to the maximum of 319 in the third week of May; and since then the numbers have been 310, 303, 249, 182, 117, 56, 40, 29, 18, 17, and 6 in the first week of August. During these 16 weeks, the total number of deaths has been 1,925 recorded as caused by influenza alone, and to this must be added a very large number due to complications with other diseases.

The excess over the average mortality was comparatively small at all ages under 20; but above 20 the excess of the mortality rose steadily with age. Thus for the six weeks beginning with May 16th, the death-rate at 80 years and upwards was 117 per cent. above the average of the season. The deaths from influenza account only for a very small fraction of the increased total mortality of London during the epidemic. Other diseases showed an extraordinarily high death-rate of which the weather at the time affords no explanation; again pointing clearly to something of an exceptional character in operation at the time.

The weekly mortalities from the various registered causes of death have been compared with their averages for these weeks, with the result that during the epidemic the death-rate was enormously increased from diseases of the respiratory organs, the circulatory system, brain diseases, and phthisis.

Now the winter of 1890–91 was, in London, one of the severest on record, the mean temperature for the eight weeks beginning with the last week of November having been 10°·4 below the average. This unprecedentedly low temperature, prolonged through many weeks, was accompanied with a correspondingly high mortality, particularly from diseases of the respiratory organs and the circulatory system; and thus during last winter the death-rate was unusually large from these diseases.

The most noteworthy circumstance connected with the recent epidemic of influenza is the lateness in the season of the time of its occurrence, the time being the end of spring and the beginning of summer. All the previous epidemics, for which trustworthy weekly

INFLUENZA, 1891.

PER-CENTAGES by which the Death-rates of London, from different Causes of Death, were above or below the Means of the previous 10 Years, 5·5 per cent. being added for increase of Population. Figures in *italics* show a per-centage above the Mean; and figures in Roman type a per-centage below it.

—	Nov. 1890.		Dec. 1890.					Jan. 1891.				Feb. 1891.			
Week	47	48	49	50	51	52	53	1	2	3	4	5	6	7	8
Mean temp.	*7°·7*	7°·0	6°·2	11°·0	13°·5	11°·7	10°·6	10°·8	7°·7	4°·5	*5°·4*	*0°·6*	1°·8	1°·4	1°·2
Sex:—															
Males	2	8	*7*	*5*	*25*	*16*	*34*	*24*	*18*	*7*	4	9	4	*4*	*15*
Females	9	5	*2*	*1*	*34*	*25*	*38*	*34*	*36*	*18*	1	11	12	*7*	*13*
Total	5	6	4	*3*	*29*	*20*	*36*	*29*	*27*	*12*	2	10	8	*5*	*14*
Ages:—															
0–5 years	10	24	4	6	*2*	3	*4*	*4*	1	3	12	27	23	11	*3*
5–20 "	6	14	1	8	15	14	*3*	*14*	6	30	20	10	20	4	11
20–40 "	1	1	6	5	*20*	*13*	*6*	*31*	*28*	*1*	14	15	*3*	*2*	*20*
40–60 "	*1*	2	*13*	*4*	*44*	*29*	*56*	*44*	*83*	*31*	*22*	7	*9*	1	*30*
60–80 "	*11*	4	*17*	*22*	*60*	*56*	*89*	*79*	*65*	*53*	*13*	11	11	*9*	*30*
80 "	*8*	*16*	*21*	*32*	*61*	*73*	*80*	*53*	*78*	*55*	*32*	7	9	*4*	*12*
Influenza	3	2	1	1	1	3	1	3	3	1	2	3	2	–	2
Circul. system	*8*	*7*	*30*	*23*	*55*	*30*	*50*	*41*	*42*	*27*	*4*	–	*8*	*19*	*33*
Pneumonia	*27*	*6*	*39*	*22*	*84*	*29*	*80*	*93*	*73*	*66*	*50*	*3*	*31*	*34*	*70*
Bronchitis	1	18	3	6	*62*	*79*	*104*	*77*	*88*	*46*	*8*	24	15	1	*41*
Pleurisy	*166*	*9*	30	*54*	*139*	*62*	*106*	*157*	–	*32*	*116*	7	*43*	*43*	*55*
Croup	32	40	*1*	24	56	33	33	36	41	47	60	33	14	40	*20*
All resp. organ diseases.	2	12	–	2	*60*	*58*	*82*	*70*	*68*	*42*	*13*	18	8	*5*	*42*
Phthisis	*4*	10	*15*	7	*27*	*5*	*2*	*1*	*14*	4	25	3	3	2	*3*
Enteritis	*21*	*53*	72	55	*78*	15	*45*	3	6	36	*75*	*75*	*14*	*22*	*93*
Apoplexy	2	15	*2*	*12*	*10*	*4*	*28*	*19*	*7*	*2*	*14*	*19*	16	8	29
All brain diss.	3	19	–	*4*	*10*	*1*	*12*	*12*	*14*	*2*	*13*	*6*	23	13	4
Epilepsy	14	*13*	*13*	*21*	*124*	*43*	1	49	*38*	67	*83*	*26*	15	67	13

—	March 1891.					April 1891.				May 1891.				June 1891.				
Week	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Mean temp.	*5°·3*	5°·4	1°·9	0°·8	2°·0	7°·6	3°·6	4°·5	*0°·6*	*2°·2*	*4°·4*	7°·3	4°·8	*2°·2*	3°·6	*3°·9*	*3°·9*	*2°·6*
Sex:—																		
Males	*14*	–	2	4	*6*	4	*11*	*8*	*27*	*28*	*45*	*38*	*49*	*42*	*28*	*32*	*14*	0
Females	*14*	9	4	12	1	2	5	*8*	*22*	*35*	*48*	*37*	*63*	*60*	*38*	*38*	*8*	9
Total	*14*	4	3	8	*3*	*1*	*3*	*8*	25	*31*	*46*	*37*	55	*50*	*33*	*35*	*11*	5
Ages:—																		
0–5 years	*3*	13	12	20	9	12	12	10	4	*1*	*11*	4	*14*	*13*	1	4	8	23
5–20 "	*7*	17	8	4	–	4	5	7	9	10	*11*	*22*	*22*	*2*	7	2	6	10
20–40 "	*10*	*14*	7	3	–	*2*	1	*18*	*22*	*23*	*36*	*58*	*42*	*46*	*15*	*40*	*15*	*10*
40–60 "	*40*	*20*	*7*	*8*	*17*	*8*	*32*	*23*	*53*	*63*	*67*	*76*	*95*	*65*	*56*	*38*	*29*	*12*
60–80 "	*24*	2	*10*	*3*	*13*	*17*	*20*	*30*	*71*	*73*	*100*	*104*	*127*	*112*	*100*	*87*	*39*	*18*
80 "	*12*	20	6	8	5	*7*	*27*	*13*	*56*	*64*	*94*	*100*	*118*	*158*	*120*	*114*	55	*24*
Influenza	2	2	1	3	7	3	2	10	37	148	266	319	310	303	249	182	117	56
Circul. system	*32*	10	1	–	*26*	*19*	*40*	*56*	*40*	*35*	*35*	*46*	*89*	*80*	*51*	*52*	*20*	*14*
Pneumonia	*97*	*73*	*21*	*24*	*51*	*30*	*59*	*61*	*123*	*120*	*121*	*129*	*114*	*110*	*116*	*112*	*63*	*48*
Bronchitis	*30*	2	1	18	9	4	*6*	*9*	*40*	*74*	*111*	*116*	*142*	*152*	*109*	*128*	*40*	*6*
Pleurisy	*80*	*118*	*126*	3	*12*	*60*	*75*	*19*	*153*	*124*	12	24	*28*	50	*111*	30	*43*	*38*
Croup	7	50	25	*10*	18	36	16	23	30	18	48	22	31	9	92	46	54	53
All resp. organ diseases.	*37*	*11*	*5*	8	*3*	7	*18*	*22*	*60*	*72*	*95*	*100*	*116*	*119*	*91*	99	*39*	*14*
Phthisis	6	7	*10*	6	2	15	18	*2*	1	*8*	*26*	*3*	*27*	*19*	*8*	*15*	*11*	*6*
Enteritis	*91*	*92*	5	*29*	*23*	39	*58*	*58*	*40*	*83*	*90*	22	*64*	26	*122*	*15*	28	*17*
Apoplexy	*15*	14	7	2	*32*	*31*	*1*	9	*65*	*23*	*21*	*35*	*29*	12	3	*17*	6	24
All brain diss.	*13*	10	–	2	*7*	*3*	9	8	4	*9*	*13*	*13*	*25*	*13*	*5*	*9*	*2*	10
Epilepsy	*69*	21	27	*55*	*33*	*39*	*16*	*13*	*67*	*54*	*57*	42	*88*	*41*	19	*46*	*25*	*41*

statistics exist, occurred either in winter or early spring. From the termination of the severe weather of winter in the end of January to the outbreak of the epidemic in the middle of April, the death-rate from these diseases, as well as the general death-rate was very greatly less than what had been before and what followed. It was in truth the normal death-rate which was to be expected to accompany the, on the whole, greatly milder weather during these 12 weeks.

The mean temperature of the 11 weeks ending with June was exactly the average of past years, the weekly averages varying from 4°·4 above the average in the second week of May to 7°·3 below it in the following week. On the whole, then, the period was of the average temperature of the season, with fluctuations of temperature somewhat larger than usual.

In 1875 we showed* that from the middle of April to the end of June the death-rate from diseases of the respiratory organs, the circulatory system, brain diseases, and phthisis steadily diminish week by week, so that with the temperature and weather which actually occurred during this period deaths from these diseases might have been expected to have fallen off week by week.

But, with the setting-in of influenza, deaths from these diseases increased with alarming suddenness, even though, be it noted, deaths from the same diseases had been exceptionally heavy during the previous December and January.

The period of the year from the third week of April to the end of June is characterised by dryness and warmth, and statistics show it to be one of the healthiest times of the year. Indeed, at this time, no disease whatever shows a rapid increase in its death-rate, and only a few, notably bowel complaints, show the setting in of a rise in June from the annual minimum, as shown in Fig. 3.

Now, during this epidemic, no bowel complaint, with the single exception of enteritis, exhibited an increase in its death-rate; and further, no increase was apparent from any of those other diseases whose mean weekly death-rate at this season happens to be moderately high.

But the remarkable thing is this, it was just the same diseases whose death-rates were so exceptionally and enormously swelled during the influenza epidemic of January and February 1890 that have exhibited a similar exceptional and enormous increase to their death-rate.

It is a singular circumstance that in both the last influenza epidemics, the one a winter and the other a summer epidemic, croup has stood out as an exception to the other diseases of the respiratory organs, in uniformly showing a death-rate below its average; and, on the other hand, enteritis stands out as an equally striking exception to other bowel complaints, in exhibiting a death-rate above its average.

Accepting the mortality returns as revealing the diseases with which the complications with influenza occur, the important conclusion

* Journal of the Scottish Meteorological Society, Vol. IV., p. 187.

is arrived at that the complications of influenza are with special diseases only, irrespective of season. The increase to the death-rate from pneumonia, bronchitis, heart disease, and phthisis are equally enormous, whether the epidemic occurs at the season when their normal death-rates are highest, or at another season when the death-rates are falling to their annual minima.

In discussing the spread of the germs of diseases from one country to another by the intervention of winds, it has hitherto been universally assumed that is only the winds blowing over or near the surface of the earth which are concerned in the distribution of these germs. If these surface winds do not account for the successive appearances of the epidemic in different countries, it is concluded that the germs have not been transported by the winds.

This, however, is only a mode of looking at the subject which ignores the recent developments of meteorology and its teachings regarding atmospheric circulation through cyclones and anti-cyclones. As is now virtually proved, the winds in a cyclone are drawn inwards towards its centre, and then ascend in a vast aerial column to the upper regions of the atmosphere, whence again they flow as an upper current towards any anti-cyclone that may surround them. Thereafter they slowly descend along the centre of this anti-cyclone to the earth's surface, over which they are carried in every direction.

Suppose, for example, there were, as often happens, a cyclone in Russia, a vast column of air ascends from the surface, carrying with it particles of dust, germs, and other light impurities. These are then conveyed by the upper current to an anti-cyclone overspreading Western Europe, as in the supposed circumstances so often happens, and thereafter they descend to the surface with the descending current and are distributed over Western and Central Europe by winds from all points of the compass. Owing to the known rapidity of these aerial movements, two, or at most three, days are amply sufficient for this distribution.

DISCUSSION.

Dr. G. B. Longstaff, after paying tribute to the great importance and high value of the work of Sir Arthur Mitchell and Dr. Buchan, and expressing the hope that their collected papers would be republished in a more accessible form, pointed out that whenever a new disease appears medical men assign other diseases as the cause of death until the disease becomes prevalent, and that for this reason many of the deaths ascribed to bronchitis, &c. ought to have been recorded as cases of influenza. Nevertheless, the Registrar-General's returns afforded on the whole reliable average information, as was shown by the tabulation of enteritis and diarrhœa.

Dr. Gilbert stated that although the rainfall in February 1891 was smaller than that recorded in any previous month, the amount of nitrogen it contained in the form of ammonia and nitric acid was almost as great as that found in the rainfall of February in the two previous years, although this amounted to nearly 1 inch in 1890, and to 2 inches in 1889.

The quantity of chlorine in the water in February 1891, was the smallest on record, this being possibly due to the unusual absence of wind.

The Hon. Rollo Russell said that there were no authentic accounts of an attack of influenza occurring in mid-ocean or at any of our light-houses. The disease was due to infection carried along the main lines of communication. The large towns were attacked in the first instance, and then the outlying districts. The march of influenza over Europe took the same lines and came from the same locality as cholera.

Dr. Tripe (Hackney) said that true influenza was invariably preceded by epidemic pneumonia. In Hackney, horses and cats during 1889–90 were attacked by influenza six weeks before any human beings, but during the last epidemic only a short time before.

Dr. Mortimer Granville had been much impressed by the apparent prominence of almost purely physical factors in the production, in influenza, of the high bodily temperature which had been considered characteristic of the disease. These factors were, first, the displacement of the blood from the centre to the periphery by the depression of vaso-motor activity produced by the onslaught of the specific poison, whatever it was, that caused the malady; second, the conductivity of the atmosphere, dependent rather on density than temperature, although temperature came largely into play. He considered that this conductivity of the atmosphere was a factor of great importance in the production of high surface temperature, and that the duration of the disease depended especially on external conditions as regarded temperature, and particularly, as above stated, on the density of the atmosphere and its conductivity rather than on the personal state of the patient. After all other symptoms had disappeared a daily rise and fall of temperature was observed in the cases of persons resident in districts where the atmosphere is generally dense and cold. The weather played a most important part in determining the prevalence, the severity, and duration of the disease.

Mr. J. T. Roe supported the theory that the source of the influenza was to be found in the great floods in China and the resulting decay of large numbers of unburied bodies, and illustrated the possibility of the diffusion of the germs by a comparison with the distribution of dust from the Krakatoa explosion of 1883.

In reply to the Hon. Rollo Russell, **Dr. Buchan** stated that the outbreak of influenza at sea mentioned in his paper could only be accounted for on the theory of atmospherical distribution of the germs.

The President remarked that the great prevalence of influenza among members of the House of Commons appeared to be due to infection introduced by the witnesses who attended the Committees on the two important Railway Bills of the session.

Recent Hygienic Improvements in the Manufacture of Bread.

BY

John Goodfellow, F.R.M.S., Hon. Consulting Chemist to the Master Bakers' Protection Society.

Bread is such a universal and important food that any improvements in its manufacture and quality deserve recognition and consideration,

and should prove interesting to all hygienists. It will be convenient if the subject be divided into two parts :—

1. Improvements in whole-meal bread.
2. Improvements in other breads.

The writer, from many experiments performed on himself, his assistants, and on young animals, for the purpose of his work on bread as a food, has come to the conclusion that ordinary whole-meal bread is not a desirable food and acts injuriously on the intestinal tract by unduly stimulating the muscles and nerve-centres of the bowels.

The chief objections to ordinary whole-meal bread as a food are :—

1. The large per-centage of waste, averaging about 12½ per cent.
2. The increased waste of other foods produced by the ingestion of whole-meal bread.
3. The unpleasant taste produced by the comparatively flavourless particles of bran.
4. The irritating action of the bran.
5. The rapidity with which whole-meal bread becomes dry and stale.

The large per-centage of waste is a most serious objection to ordinary whole-meal bread, especially if it be taken in large quantities. It constitutes a loss of energy to the body, inasmuch as force is used to digest the extra quantity of food which must be taken to equalize the waste.

The waste in fine white bread only amounts to about 4½ per cent., so that whole-meal bread is not nearly so thoroughly digested as white bread, and its ingestion leads to an increase in the waste of other foods.

In a subject experimented on by the writer, in December 1890, it was found that when milk alone was used as a food the waste averaged about 8 per cent. ; but when ordinary whole-meal bread was used with the milk, the waste in the milk rose to nearly 11 per cent.

The irritating action of coarse whole-meal bread depends on the bran. The coarse bran particles act as mechanical stimuli, both to the nerve centres and the muscles, and unduly increase the peristaltic action of the intestines.

The stimulation often passes beyond the innocuous stage, and severe diarrhœa may be brought on by the excessive irritation of the bran. The writer has found indications that the villi of the intestines may be considerably modified by a continued ingestion of coarse bran, and he believes that this modification may have an effect in reducing the absorbing power of the villi.

Many medical authorities assert that slight chronic inflammation may result from the continual ingestion of coarse bran, and the author must admit that over and over again the post-mortem appearances of the animals he has experimented upon have been quite compatible with such a view.

The unpleasant flavour of coarse whole-meal bread is probably caused by the bran particles, which produce in the mouth an acute sense of *touch*, but not a very decided taste.

Some students undertook to test this point under the writer's direction, and they affirmed that flavourless particles very materially altered the taste of nearly every food tried.

They found, also, that the finer the particles the less they affected the flavour of the food with which they were mixed.

Objection number 5 is an important one. Very few people can partake of a stale whole-meal loaf with any degree of pleasure. It is well-known that staleness is not altogether due to a simple evaporation of water. There is a molecular change which goes on slowly, and which is an important factor in producing a stale loaf.

In ordinary whole-meal bread these changes go on very rapidly, and the bread after 24 hours is comparatively flavourless and distasteful.

The first four objections depend on the presence of coarse bran particles. It appears that very fine particles of bran do not produce such undesirable effects on the body as those which have been ascribed to coarse bran, so that the hygienic improvements in whole-meal bread must necessarily take the form of—

1st. Obtaining a *fine* bran in the loaf.

2nd. The preparation of so *dry* a meal that the bread takes up a large proportion of water, which is so intimately incorporated with the constituents as to delay those internal changes which result in a stale loaf.

Other minor improvements may also be referred to, affecting the digestibility, purity, flavour, &c., of the bread.

Number 1. Triticumina Bread.—This is a special whole-meal bread in which the bran particles are very fine, and shows what can be done in this direction. It is prepared from a special meal, ground by powerful steel machines, in which the bran is literally cut up into fine particles.

The waste in this bread, as ascertained by personal experiments, is only 7½ per cent., as compared with 12½ per cent. in ordinary whole-meal bread. The bran is so fine that it does not irritate the intestines like the coarse varieties of brown bread.

That it is perfectly possible to manufacture whole-meal bread which shall keep moist for two or three days is proved by the fact that this bread is palatable and soft after being kept three days. This is not only due to the moisture which it contains, but also to the large proportion of *soluble* matter present. The flavour of the bread is very pleasant owing to the large quantities of sugar and dextrin which it contains.

This bread is also distinctly very digestible. The starch is in a very assimilable condition, and there is about 50 per cent. more soluble matter present than in ordinary whole-meal bread.

This very desirable result is obtained by allowing the grain to undergo the first stages of germination, and subsequently kiln-drying it at a low temperature.

Number 2. "Cyclone" Bread is very interesting as marking a new departure in the preparation of whole-meal. The wheat grains are pulverized in sealed chambers by means of air-currents produced by fans

rapidly revolving in different directions. The grains are reduced to a state of fine division by their own momentum, and the result is a fine whole-meal. The advantages of this method are many. In the first place the meal is thoroughly aërated, and, secondly, there is no metallic or stony adulteration; thirdly, the meal is very free from microbes and other aërial impurities, for the air is filtered before being delivered to the chambers.

These two specimens demonstrate the possibility of manufacturing whole-meal bread in which the bran particles are so fine as to entirely obviate any irritating effects.

Improvements in non-whole-meal breads.

These may be divided into:—

1. Improvements in white bread.
2. Improvements in brown bread.

White bread is certainly deficient in proteid material, fat, and mineral matter. The reason of this is well-known. Fine white flour is obtained chiefly from the centre of the grain, and the bran and the germ are rejected. The bran and the germ are the portions of the grain richest in proteids, fat, and mineral matter, while the central part is poor in proteids and phosphates, and rich in starch.

Hence it follows that bread made from fine white flour is also deficient in nitrogenous matter, fat, and inorganic constituents, and is correspondingly rich in starch.

Any process, therefore, which secures:—

1. A higher per-centage of proteids;
2. ,, ,, fat;
3. ,, ,, phosphates;

may be regarded as an hygienic improvement in the quality of the bread. There appears to be a consensus of opinion that if a larger per-centage of our carbo-hydrate food took the form of soluble bodies (sugar and dextrin) the economy would gain considerably by such a substitution. Any process, then, which secures this, may also be regarded as an hygienic improvement, inasmuch as the bread would be more digestible.

The standard ratio of nitrogenous matter to carbo-hydrate material may be taken as 1 is to 3·2. The ratio in ordinary fine white bread is as 1 is to 7.

Number 3. Black's Fermented Bread is a white bread which is characterised by a high per-centage of nitrogen.

This result is obtained by a special process in which "strong flours" are taken and formed into dough, and then treated with lime-water. The gluten is concentrated, and part of the starch precipitated, so that a dough is obtained very rich in proteid material. This dough is then added to ordinary dough, and the result is a mixture with a very high proportion of albuminoid matter.

This characteristic is obtained without any deterioration of texture or flavour, and the ratio of nitrogenous matter to carbo-hydrates is as 1 is to 3·6, very near the normal.

This bread, though white, has quite as high a per-centage of proteid material as fine whole-meal.

Number 4. Diastase Bread is a variety with a very high percentage of soluble carbo-hydrates, chiefly in the form of maltose. The starch is also in a very assimilable form. The bread has a very fine texture, and is one of the best flavoured of the white breads. It keeps moist far longer than ordinary white bread, for the diastase so acts on the starch as to produce soluble bodies which confer this characteristic on the bread.

The ratio of nitrogenous matter to carbo-hydrates is about the same as in ordinary fine white bread, but the bread is far more digestible, containing quite 80 per cent. more soluble carbo-hydrates.

This result is obtained by the addition of "diastase" to the dough, which acts on the starch, converting it into several forms of dextrin and sugar. The whole series of intermediate changes have not yet been fully worked out, but it appears that maltose is chiefly formed as a final product, and one of the achro-dextrins. The diastase does very little work during the doughing stage, but when the dough is introduced into the oven it rapidly acts on the gelatinized starch, until its power is destroyed by the heat of the oven.

The author has ascertained that 15 minutes is the average time during which the ferment acts on the starch in the oven, quite long enough for the diastase to produce a considerable quantity of sugar.

Brown Breads.

Number 5. Frame Food Bread.

This bread is made from ordinary white flour, to which an extract of bran is added. The extract is prepared by mechanical means from the bran, and consists of the following bodies :—

Water - - -	9·58
Carbo-hydrates - -	58·33
Proteids - -	21·40
Mineral matter - -	10·69
	100·00

The mineral matter is very rich in alkaline phosphates.

The extract may be added to the dough either as a powder or as a liquid, the object of the addition being to get a loaf having the same composition as whole-meal bread minus the bran particles.

The ratio of proteids to carbo-hydrate is as 1 is to 3·9, very much higher than in the case of fine white bread, and the bread contains 50 per cent. more mineral matter, consisting chiefly of phosphoric acid and potash.

Number 6. Germ Bread is manufactured from "germ" flour. Germ flour consists of about 75 per cent. of ordinary white flour, and 25 per cent. of the germ.

The germ being the embryo of the *Triticum* is rich in proteids, fat, and phosphates, and its retention in the flour adds materially to the nutritive value of the bread. The germ is specially treated in order to destroy the ferments and the bitter principle found in it. This bread is very rich in proteids, and contains far more fat and phosphates than ordinary bread. The ratio of protcids to carbo-hydrates is as 1 is to 3, slightly higher than the normal.

Number 7. Health Bread. This variety contains all parts of the wheat grain except the outer layers of the bran. The bread is thus free from irritating particles, while it retains the nutritious elements of the wheat. The ratio of nitrogenous matter to carbo-hydrate material is as 1 is to 3·6.

The process of preparation of the meal secures the rejection of the outer layers of the bran, consisting chiefly of woody fibre, while the inner layers containing the nutriment are retained and finely granulated.

I have only time to mention the existence of various malted breads, prepared by the addition of malt extract to the dough. Such breads are better flavoured and more digestible than ordinary bread, and there is very little risk of sourness. The malt favours quick fermentation, so that the souring germs are never allowed to develop in the dough, owing to the vigorous growth of the yeast and a minimum production of alcohol. The working is also cleaner, for potatoes need not be used when malt extract is employed.

Machine-made bread is coming more and more to the front, and rightly so. Such bread is surely to be preferred before hand-made bread, with the possible contingency of contamination from the bodies of the half naked operatives.

When it is impracticable to put down an extensive plant, hand-machines are used now in most bakeries, including such contrivances as kneaders, dough dividers, potato washing machines, flour blenders, &c.

The sanitary condition of bakehouses has of late years undergone much improvement, and it is rare indeed to find now-a-days dirty and unhealthy premises used for the purpose of bread-making.

I desire to record my sincere thanks to my assistant, Mr. D. J. Knightley, for the able manner in which he carried out my instructions while living on certain breads alone, and to my colleague Mr. C. H. Clarke, M.R.A.S., for confirming the analyses. I also wish to acknowledge my indebtedness to Dr. Frankland, F.R.S., for one of the analyses.

DISCUSSION.

Dr. Van Hamel Roos (Amsterdam) asked to what extent the mineral matter had been increased by adding lime water to the meal, and whether by lime water was meant a saturated solution of lime. He added, that, as editor of the "International Review of Adulterations," he was opposed to the adding of any foreign mineral matter to our food.

In reply to a question of Sir Roscoe as to whether copper salts were used in bakery in Holland, Dr. Van Hamel Roos answered that he never had found any in the meal and bread under his observation. Formerly it was met with in Amsterdam, but the adulteration was detected at once, as large crystals of copper sulphate were found in the bread. As to alum, he said that baking powders recommended as being used for improving bread on a large scale in England had been analysed by him and found to consist of alum. He thought these additions to meal and bread ought to be strictly prohibited.

Sir Charles Cameron said that it was undesirable to introduce indigestible and rough particles into the digestive organs. He had met many cases of suspected poisoning of oxen and sheep in which he was able to trace the real cause of death to the irritative action of undecorticated cotton cake, and even of other food stuffs. He thought the popular instinct was right when on the whole people preferred beautiful white bread, which they felt they could digest with comfort. Referring to Lawes' and Gilbert's experiments, Sir C. Cameron believed that a bread diet was more nitrogenous than a meat one, and therefore, that although white contained less nitrogen than brown bread, yet there was a sufficient amount of nitrogen in the former.

Mr. Cassal was glad that Dr. Van Hamel Roos had attended the Section, as he was editor-in-chief of the very important "International Review of Adulterations," by means of which it might be hoped that in the near future united action would be taken by different countries for the suppression of adulteration. In regard to the use of sulphate of copper and alum in bread-making, he had always understood that the main object was to prevent fermentation from going too far when yeast was used, thus giving a badly coloured and acid bread; and also to enable damaged flours to be used by bakers.

Bromine and Iodine as Aërial Disinfectants; and on a new Method of Applying them.

BY

Gerald T. Moody, D.Sc., and F. W. Streatfeild.

The question of suitable aërial disinfectants for employment in hospitals, sick rooms, &c. is one of very great importance, and has not perhaps hitherto received the attention it deserves. Of the various substances employed, bromine has come largely to the front in recent years, and iodine has also been found to exert a considerable disinfecting action, although less than that of bromine weight for weight. Considerable difficulty has, however, been experienced in finding a suitable and convenient method of introducing these elements into the atmosphere. Various forms of lamps have been devised for the gradual volatilization of iodine and its diffusion through the air; and many have sought to effect the same purpose through the medium of the candle or night light. Whilst working in this direction, and with the endeavour to volatilize by means of a burning candle certain volatile brominated

organic derivatives of the aromatic series, it was discovered by one of the authors that *free* bromine vapour was evolved in quantity during the combustion of the candle. On extending the experiments to iodine derivatives a similar result was obtained. The authors therefore turned their attention to the preparation of a satisfactory bromine and iodine candle.

A modern candle is a very delicate piece of work, being the outcome of many years' experience and of much scientific and technical skill. Next to the proper refining of the fat or wax, the fabrication and chemical treatment of the wick are points of great importance, in order that the candle may burn with a bright flame, and free from cauliflower head. A very small quantity of a foreign body introduced into the substance of the candle causes a very marked effect on its combustion. Many of the disinfectants proposed for distribution by the aid of the candle caused it to burn very indifferently, and sometimes to be extinguished within an hour; or worse still, where it was sought to diffuse the vapour of certain balsamic or phenolic principles, the "disinfectant" itself underwent combustion and thus defeated the object in view. In the case where the free halogen was simply mixed with the combustible material of the candle, failure resulted from the escape of part of the halogen during storage, whilst the remainder gradually destroyed the material of the wick. After making numerous experiments the above-mentioned difficulties were overcome, and the authors succeeded in preparing candles and night-lights which do not undergo change on keeping, and by means of which any required quantity of the halogens bromine and iodine may be evolved with great exactness. This result has been accomplished by incorporating stable haloid organic compounds with the substance of the candle or night-night. Up to the present the most successful halogen compounds used have been dibromonaphthalene $C_{10} H_6 Br_2$ and iodoform CHI_3. These substances are perfectly stable at ordinary temperatures, but when burnt under the conditions obtaining in a candle or night-light prepared from pure, well-pressed tallow, give rise to free bromine or iodine vapour respectively.

That the free halogen is evolved is shown by the odour produced; and its presence may be visibly demonstrated by the usual chemical method of holding at a short distance above the flame a piece of unsized paper moistened with a solution of starch and potassium iodide, which is rapidly turned blue.

The liberation of bromine and iodine during combustion may probably be explained on the assumption that the corresponding hydracids are formed in the first instance, and that these suffer decomposition at the temperature of the flame and in the presence of atmospheric oxygen into the free halogens and water, in accordance with the equations—

$$\text{(i.)} \quad 4HBr + O_2 = 2H_2O + 2Br_2$$

Hydrogen bromide and oxygen give water and bromine.

$$\text{(ii.)} \quad 4HI + O_2 = 2H_2O + 2I_2$$

Hydrogen iodide and oxygen give water and iodine.

The authors found that a very useful strength for general purposes is about 6 grains (0·3886 gram.) of either halogen compound in a 9-hour night-light; during eombustion this will liberate bromine or iodine, the amount of which may be calculated as follows:—

The iodine night-light contains 6 grains of CHI_3, — C, $12 \times 1 = 12$; H, $1 \times 1 = 1$; I_3, $127 \times 3 = 381$; or, 394 grains of iodoform yield 381 grains of iodine; consequently 6 grains of iodoform in a night-light will give $\frac{381 \times 6}{394} = 5{\cdot}80$ grains of iodine liberated during the nine hours.

The bromine night-light contains 6 grains of $C_{10} H_6 Br_2$; as before, — C_{10}, $12 \times 10 = 120$; H_6, $1 \times 6 = 6$; Br_2, $80 \times 2 = 160$; or the total 286 grains of dibromonaphthalene yield 160 grains of bromine, and eonsequently 6 grains of dibromonaphthalene will give 3·35 grains of bromine during nine hours.

By means of the above calculations it is easy to bring about the evolution of a stated quantity of either halogen, as during each hour's burning there will be evolved, of free iodine 0·64 grain, of free bromine 0·37 grain. By increasing or diminishing the quantity of the halogen compound mixed with the candle or night-light, any quantity of halogen, within reasonable limits, may be diffused.

The authors believe that the hygienic value of their discovery is very great, since it will make it possible for the vapour of bromine to be used as a household disinfectant in a safe and effieient manner and where it will be likely to do most good. It is espeeially for sanitary purposes that the bromine eandle or night-lights are most likely to be useful, and there is no doubt they will prove of serviee for disinfecting closets, lavatories, and wherever sources of infection have to be guarded against. It must be understood that the bromine vapour evolved by the burning candle or night-light does not cause the slightest personal inconvenicnee in practice, eandles containing about 6 grains of dibromonaphthalene having been burnt nightly by one of the authors during a period of two years. All the time the eandle is burning the odour of bromine in the room is distinctly pereeptible, but by no means disagreeable. Similar remarks apply to the iodine candle or night-light, which, besides being effective as a disinfectant and deodorant, has the advantage of possessing a therapeutical value in diseases of the throat, nose, and lungs.

DISCUSSION.

Mr. Cassal said that he had had occasion to examine these night-lights and could confirm the liberation of free iodine and bromine from them on burning, a fact which was in itself interesting; but he did not see that there was any special value attaching to such liberation for purposes of deodorisation or disinfection, and certainly not in regard to the latter.

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